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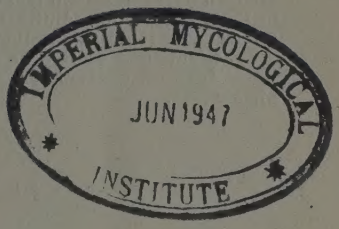

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MATHEMATICS

SOLUTION OF SOME BOUNDARY PROBLEMS FOR ELLIPTICAL SYSTEMS OF LINEAR EQUATIONS

By N. I. SIMONOV

(Communicated by S. N. Bernstein, Member of the Academy, 28.II.1944)

Let us consider a system of linear equations with real constant coefficients

$$\sum_{s=1}^{2}\left[a_{nn}^{(ks)}\frac{\partial^2 u_s}{\partial x_n^2}+\sum_{p,q=1}^{n}a_{pq}^{(ks)}\frac{\partial^2 u_s}{\partial x_p \partial x_q}\right]=0 \quad (k=1,2) \tag{1}$$

This system is an elliptical system if the determinant

$$D=D(\alpha_1,\ldots,\alpha_n)=\begin{vmatrix} a_{nn}^{(11)}\alpha_n^2+\sum_{p,q=1}^{n-1}a_{pq}^{(11)}\alpha_p\alpha_q & a_{nn}^{(12)}\alpha_n^2+\sum_{p,q=1}^{n-1}a_{pq}^{(12)}\alpha_p\alpha_q \\ a_{nn}^{(21)}\alpha_n^2+\sum_{p,q=1}^{n-1}a_{pq}^{(21)}\alpha_p\alpha_q & a_{nn}^{(22)}\alpha_n^2+\sum_{p,q=1}^{n}a_{pq}^{(22)}\alpha_p\alpha_q \end{vmatrix}$$

takes none but positive values for all such real values of the parameters α_p, α_q that are not simultaneously equal to zero.

Assuming the ellipticity condition

$$D(\alpha_1,\ldots,\alpha_n)>0 \tag{2}$$

to be fulfilled, we shall consider the following boundary problem. Find in the domain

$$-\infty<x_j<\infty \quad (j=1,2,\ldots,n-1)$$
$$x_n>0 \tag{3}$$

a solution of system (1) satisfying in the plane $x_n=0$ to the boundary conditions

$$L_s(u_1,u_2)\equiv\left[r_{11}^{(s)}u_1+r_{12}^{(s)}u_2+r_{11}^{(s)}\frac{\partial u_1}{\partial x_n}+r_{12}^{(s)}\frac{\partial u_2}{\partial x_n}\right]_{x_n=0}=f_s(x_1,x_2,\ldots,x_{n-1}),\ s=1,2$$

Here the $r_{pq}^{(s)}$ are real constants and the $f_s(x_1,\ldots,x_{n-1})$ $(s=1,2)$ are continuous and bounded, as are also their partial derivatives up to the order $2(n+1)$ inclusive. The conditions which the $r_{pq}^{(s)}$ should satisfy are specified later.

By suitably modifying the method based on the use of Fourier transformation, by means of which very general results are obtained in the theory of

Cauchy problem (1), we shall for $n>2$ get the solution of our problem in the form

$$u_s(x_1, x_2, \ldots, x_n) = \int_{-\infty}^{\infty} \cdots \int_{-\infty}^{\infty} \Big[E_{f_1}(\alpha_1, \alpha_2, \ldots, \alpha_{n-1})\, v_1^{(s)}(\alpha, x_n) +$$

$$+ E_{f_2}(\alpha_1, \alpha_2, \ldots, \alpha_{n-1})\, v_2^{(s)}(\alpha, x_n)\, e^{\,i \sum_{k=1}^{n-1} \alpha_k x_k} \Big]\, d\alpha_1 \ldots d\alpha_{n-1}$$

Here

$$E_{f_k}(\alpha_1, \ldots, \alpha_{n-1}) = \frac{1}{(2\pi)^{n-1}} \int_{-\infty}^{\infty} \cdots \int_{-\infty}^{\infty} f_k(\xi_1, \ldots, \xi_{n-1})\, e^{\,-i \sum_{k=1}^{n-1} \alpha_k x_k}\, d\xi_1 \ldots d\xi_{n-1},$$

and the functions

$v_k^{(1)}(\alpha, x_n) \equiv v_k^{(1)}(\alpha_1, \ldots, \alpha_{n-1}, x_n)$, $v_k^{(2)}(\alpha, x_n) \equiv v_k^{(2)}(\alpha_1, \ldots, \alpha_{n-1}, x_n)$ $(k=1,2)$ are two solutions of a system of ordinary differential equations

$$\sum_{s=1}^{2} \left\{ a_{nn}^{(ks)} \frac{d^2 v_k^{(s)}(\alpha, x_n)}{dx_n^2} - \Big[\sum_{p,q=1}^{n-1} a_{pq}^{(ks)} \alpha_p \alpha_q \Big] v_k^{(s)}(\alpha, x_n) \right\} = 0 \qquad (k=1,2) \tag{4}$$

satisfying, respectively, the conditions

$$\begin{aligned} L_1(v_1^{(1)}, v_1^{(2)}) &= 1, \quad L_1(v_2^{(1)}, v_2^{(2)}) = 0 \\ L_2(v_1^{(1)}, v_1^{(2)}) &= 0, \quad L_2(v_2^{(1)}, v_2^{(2)}) = 1 \end{aligned} \tag{5}$$

The coefficients $r_{pq}^{(s)}$ are supposed to be such that for all real values of $\alpha_1, \alpha_2, \ldots, \alpha_{n-1}$ not simultaneously equal to zero the inequality

$$\begin{vmatrix} L_1(w_1^{(1)}, w_1^{(2)}) & L_1(w_2^{(1)}, w_2^{(2)}) \\ L_2(w_1^{(1)}, w_1^{(2)}) & L_2(w_2^{(1)}, w_2^{(2)}) \end{vmatrix} \neq 0$$

is satisfied if $w_k^{(1)}$, $w_k^{(2)}$ $(k=1,2)$ are linearly independent solutions of the system (6). This condition amounts to the demand that a certain quadratic equation whose coefficients depend on $r_{pq}^{(s)}$ (and $a_{pq}^{(s)}$) should have no real roots.

For $n=2$ the solution has the form

$$u_s(x_1, x_2) = \int_0^{\infty} [E_{f_1}(\alpha)\, v_1^{(s)}(\alpha, x_2) + E_{f_2}(\alpha)\, v_2^{(s)}(\alpha, x_2)]\, e^{i\alpha x_1} d\alpha +$$

$$+ \int_{-\infty}^{0} [E_{f_1}(\alpha)\, \overline{v}_1^{(s)}(\alpha, x_2) + E_{f_2}(\alpha)\, \overline{v}_2^{(s)}(\alpha, x_2)]\, e^{i\alpha x_1} d\alpha$$

where the functions $v_k^{(1)}(\alpha, x_2)$, $v_k^{(2)}(\alpha, x_2)$ and $\overline{v}_k^{(1)}(\alpha, x_2)$, $\overline{v}_k^{(2)}(\alpha, x_2)$ $(k=1,2)$ are the solutions of the system (4) for $n=2$ which satisfy the conditions (5). The use of this method and of the corresponding theorems of variational calculus makes it possible in the case of the first boundary problem to explore, moreover, the question on the uniqueness of the solution when an additional condition determining its behaviour at infinity is imposed.

Suppose that for the elliptical system (1) a positive definite quadratic form

$$K = K\left(\frac{\partial u_1}{\partial x_1}, \ldots, \frac{\partial u_1}{\partial x_n}, \frac{\partial u_2}{\partial x_1}, \ldots, \frac{\partial u_2}{\partial x_n}\right)$$

can be constructed such that (1) will be a system of Euler's equations in the problem of finding min $\iint K\,dx_1\,dx_2$. It should be noted that in the general case the ellipticity condition alone will not suffice for this construction; if the system contains no mixed derivatives, the necessary and sufficient condition for the existence of the form K is that the coefficients $a_{pp}^{(hs)} = a_{pp}^{(sk)}$ (2) be symmetrical.

Let it be required now to find in the domain (3) a solution satisfying the boundary conditions

$$u_s(x_1, x_2, \ldots, x_{n-1}, 0) = f_s(x_1, \ldots, x_{n-1}),$$
$$|u_s| \to 0, \text{ if } r = \sqrt{\sum_{i=1}^{n} x_i^2} \to \infty \qquad (6)$$

If the f_s are continuons and so are also their partial derivatives of order one, then assuming the products $|f_s x_1 x_2 \ldots x_{n-1}|$ to be integrable, the follow ing statement will be valid. The proposed problem with boundary conditions (6) has a solution which is moreover the only possible one. This solution varies continuously with f_1 and f_2. Thereby the correctness of the formulation of our boundary problem is proved.

The method can be employed in the case of more complicated equations containing terms of lower orders. Thus, the theorem asserting that the first boundary problem admits a solution in the domain (3) can without substantial modifications be proved for the general linear elliptic equation

$$\sum_{s,k=1}^{n} a_{sk} \frac{\partial^2 u}{\partial x_s \partial x_k} + \sum_{s=1}^{n} b_s \frac{\partial u}{\partial x_s} + cu = 0, \quad \sum_{s,k=1}^{n} a_{sk} \alpha_s \alpha_k > 0, \; c < 0$$

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MATHÉMATIQUES

SUR LA MEILLEURE APPROXIMATION

Par A. MARKOUCHEVITCH

(Présenté par S. N. Bernstein, de l'Académie, le 24.XII.1943)

1. Soit E un espace métrique linéaire, $\{u_n\}$ une suite quelconque d'éléments de cet espace qui sont linéairement indépendants, et U l'enveloppe linéaire fermée de $\{u_n\}$. Soit $u \in U$; le nombre

$$E_n u = \inf_{x_0,\ldots,x_n} \| u - x_0 u_0 - \ldots - x_n u_n \|,$$

où $\|e\|$ désigne la norme de l'élément e, sera nommé la meilleure approximation de u dans U au moyen de polynômes par rapport à $\{u_n\}$. Il est évident que $E_n u \geqslant E_{n+1} u \geqslant 0$ et que $\lim_{n\to\infty} E_n u = 0$.

Dans le cas où E est, par exemple, un espace du type B, c'est-à-dire un espace complet, linéaire et métrique où la norme vérifie la condition $\|ae\| = |a| \|e\|$ (a est un nombre), il est facile à voir qu'il existe pour chaque n au moins un polynôme dont l'écart de u est minimal:

$$\pi_n = x_0 u_0 + \ldots + x_n u_n$$

c'est-à-dire tel que $\|u_n - \pi_n\| = E_n u$.

2. En suivant les idées classiques de S. N. Bernstein nous allons donner une classification des éléments de $u \in U$ d'après la vitesse avec laquelle les nombres $E_n u$ tendent vers zéro. Considérons le cas d'un espace du type B. Si tous les $E_n u$ à partir d'un certain $n = n_0$ sont nuls, u est un polynôme de degré n_0 au plus. Posons la question: comment peut on exprimer au moyen de $E_n u$ les conditions dans lesquelles u peut être présenté comme somme d'une série en $\{u_n\}$? Pour répondre à cette question supposons que le système $\{u_n\}$ est fortement linéairement indépendant (1), c'est-à-dire que la convergence vers zéro de chaque suite de polynômes $p_n = a_0^{(n)} u_0 + \ldots + a_n^{(n)} u_n$ entraîne toujours la convergence vers zéro de la suite des coefficients dane chaque colonne: $\lim_{n\to\infty} a_m^{(n)} = 0$ $(m = 0,1,2, \ldots)$. C'est équivalent (1) à l'hypothèse qu'il existe un système de fonctionnelles linéaires $\{L_n\}$ biorthogonal par rapport à $\{u_n\}$, c'est-à-dire tel que $L_n u_m = \delta_{nm}$, où $\delta_{nm} = 0$ pour $n \neq m$ et $\delta_{nn} = 1$. Dans ces hypothèses on obtient

$$\| \pi_n - \sum_{j=0}^{n} L_j u \cdot u_j \| \leqslant M_n \cdot E_n u, \qquad (1)$$

où M_n désignant la norme de l'opérateur linéaire $\sum_{j=0}^{n} L_j u \cdot u_j$ est un nombre positif qui ne dépend que de la suite $\{u_j\}$ et de n. Il en résulte que l'on a le

Théorème 1. *Si $\{u_n\}$ est un système fortement linéairement indépendant d'éléments d'un espace du type B, $\{L_n\}$—un système de fonctionnelles linéaires biorthogonal à $\{u_n\}$ et M_n—la norme de l'opérateur linéaire $\sum_{j=0}^{n} L_j u \cdot u_j$, alors la condition*

$$\lim_{n\to\infty} M_n \cdot E_n u = 0 \tag{2}$$

entraîne la convergence de la série $\sum_{j=0}^{\infty} L_j u \cdot u_j$ vers u, et la condition

$$\lim_{n\to\infty} M_n \cdot E_n u = 0 \tag{3}$$

a pour conséquence que la série $\sum_{j=0}^{\infty} L_j u \cdot u_j$ possède une suite de sommes partielles qui converge vers u.

Pour illustrer le théorème 1 indiquons que dans le cas de l'espace C des fonctions continues et périodiques de période 2, comme, par exemple, la suite $\frac{1}{\sqrt{2}}$, $\cos \pi x$, $\sin \pi x$, $\cos 2\pi x$, ... les constantes M_n sont les constantes de Lebesgue et la série $\sum_{j=0}^{\infty} L_j u \cdot u_j$ est la série de Fourier de la fonction continue $u = u(x)$. Les conditions (2) et (3) prennent ici la forme:

$$\lim_{n\to\infty} \ln n \cdot E_n u = 0 \text{ et } \lim_{n\to\infty} \ln n \cdot E_n u = 0.$$

Remarquons que des légères modifications suffisent pour que le théorème 1 soit encore vrai pour des espaces plus généraux que ceux du type B, par exemple, pour les espaces du type F [voir les définitions et les propriétés les plus simples dans (²)].

3. Revenons maintenant au cas général d'un espace métrique linéaire arbitraire E. On obtient ici sans difficulté la proposition suivante:

Théorème 2. *Si u est un élément arbitraire de l'enveloppe linéaire fermée U des éléments $\{u_n\}$, et $\{\varepsilon_n\}$ est une suite monotone de nombres positifs qui converge vers zéro aussi vite que l'on veut, il existe toujours deux éléments $u' \in U$ et $u'' \in U$ tels que $u' + u'' = u$, et d'ailleurs*

$$\lim_{n\to\infty} \frac{E_n u'}{\varepsilon_n} = 0, \quad \lim_{n\to\infty} \frac{E_n u''}{\varepsilon_n} = 0 \tag{4}$$

Pour le démontrer construisons d'une manière récurrente une suite de polynômes $\{p_n\}$ qui converge vers u. Posons $p_1 = u_1$; si l'ordre de p_n est m_n, nous choisirons p_{n+1} de telle manière que $m_{n+1} > m_n$ et que $\| u - p_{n+1} \| < \frac{\varepsilon_{m_n}}{2^{n+1}}$. Alors en posant $p_0 = 0$, où 0 est le zéro de l'espace, nous aurons

$$u' = \sum_{1}^{\infty} (p_{2n} - p_{2n-1}), \quad u'' = \sum_{1}^{\infty} (p_{2n-1} - p_{2n-2})$$

En effet, il est évident que $u'+u''=u$. D'ailleurs, $\sum_{1}^{N}(p_{2n}-p_{2n-1})=P_N$ est un polynôme de degré m_{2N} pour lequel on a

$$E_{m_{2N}}u' \leqslant \|u'-P_N\| \leqslant \sum_{n=N+1}^{\infty} \|p_{2n}-p_{2n-1}\| \leqslant \frac{\varepsilon_{m_{2N}}}{2^{2N}}$$

c'est-à-dire $\lim_{N\to\infty} \frac{E_{m_{2N}}u'}{\varepsilon_{m_{2N}}}=0$.

Le théorème est démontré. Comme une application intéressante de ce théorème indiquons la proposition suivante:

Théorème 2_1. *Chaque fonction continue $u(x)$ est la somme de deux fonctions quasi-analytiques (P).*

Rappelons qu'une fonction $f(x)$ continue sur le segment $[-1, +1]$ est nommée quasi-analytique (P) (S. N. Bernstein), si la condition suivante est remplie

$$\lim_{n\to\infty} \frac{E_n f}{\rho^n}=0$$

où $0<\rho<1$ et $E_n f$ est la meilleure approximation de $f(x)$ sur $[-1, +1]$ au moyen de polynômes de la forme $x_0+x_1x+\ \ldots\ +x_nx^n$.

Ce théorème est analogue au théorème suivant de Mandelbroyt [3]: Chaque fonction infiniment dérivable $u(x)$ est la somme de deux fonctions quasi-analytiques (D).

On sait [4] qu'une fonction peut être quasi-analytique (P) sans être quasi-analytique (D), et inversement.

4. En réunissant les théorèmes 1 et 2 on obtient la propositon suivante [1]-

Théorème 3. *Si $\{u_n\}$ est un système fortement linéairement indépendant, formé d'éléments d'un espace linéaire du type B (ou, plus généralement, du type F) et $\{L_n\}$ est un système de fonctionnelles linéaires biorthogonal par rapport à $\{u_n\}$, alors chaque élément u qui appartient à l'enveloppe linéaire fermée de $\{u_n\}$, peut être présenté comme somme $u=u'+u''$ d'éléments tels que les séries $\sum_{0}^{\infty} L_nu' \cdot u_n$ et $\sum_{0}^{\infty} L_nu'' \cdot u_n$ possèdent chacune une suite de sommes partielles convergeant respectivement vers u' et u''.*

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ASTRONOMY

HYDROGEN EMISSION LINES IN THE SPECTRA OF LONG PERIOD VARIABLE STARS

By G. A. SHAJN, Member of the Academy

The problem of emission lines in the spectra of long period variables must be intimately connected with the general problem of these stars. Hitherto the origin of emission lines in these cold stars remains quite enigmatic. This paper is a brief account of some new results on hydrogen emission lines, which will probably be of value for the elucidation of the problem as a whole.

1. The width of emission lines in these stars is unknown. It is self-evident that very much would be gained even if only the order of this quantity were estimated. The author was able to estimate the width in the following manner. In the region 3800—3900 the dispersion used is about 22Å/mm, and the hydrogen emission lines in the spectra of o Ceti and χ Cygni are sensibly wider here than the iron lines of the same intensity in the comparison spectrum. Allowing in a rough manner for the influence of the instrumental profile, we found the width of H_{11} and H_8 to be about 0.6 Å. It is further a well-known fact that some emission lines appear to be double or even triple. The cause of the decrease of emission in the central portion of the profile is due, at least for some of the lines, to the influence of absorption lines. For instance, the division of H_{16} is due to the low-temperature line V I 3703.6. Even when using a moderate dispersion, the distance between the components of H_{16} and H_{10} may be measured with certainty. This distance which turned out to be about 0.6 Å evidently represents the minimum value of the line width. At last one may judge of the width from the excellent large scale spectrogram (2.9 Å/mm) of o Ceti recently obtained by Adams (1). Selecting not overexposed emission lines not affected sensibly by absorption lines we find their width to be of the order of 0.6 Å. Therefore the width of hydrogen emission lines in the region 3700—3900, as estimated independently in three different ways, turns out to be about 0.6 Å, that is several times as great as the Doppler thermal width for T adopted for these stars.

2. The known anomalies in the intensities of Hε, Hγ, Hβ, Hα have long been interpreted in terms of the hypothesis of overlying absorption (Ti O, Ca II), though the phenomenon is actually much more complicated than what it appears to be at first sight. The Balmer decrement within H_8—H_{16} seems to be more «normal», though several lines show a fairly notable anomaly. The term «anomaly» is understood here to have a wider sense than usual. In addition to the intensity anomaly one must also consider the anomaly in the wave-length and the anomaly in the structure of lines. Below are confronted these three characteristics for H_8—H_{16}, using for the first two of them our own measurements and estimates. With respect to the measured deviations in λ we have good agreement with Merrill (2). As to the line structure the above-mentioned spectrogram by Adams has proved to be very useful.

Lines	Deviation in Å	Weakening	Structure
H_{16} 3703.85	—	Very strong	Distinct division
H_{15} 3711.97	0?	0?	Possibly insignificant asymmetry V
H_{14} 3721.94	0?	Very strong	Width nearly twice as small as for other lines
H_{13} 3734.37	—0.04	Small	Small asymmetry R
H_{12} 3750.15	+0.28	Very sensible	Strong asymmetry V
H_{11} 3770.63	0.00	0	Complete symmetry
H_{10} 3797.90	—0.20	Small	Sensible asymmetry R, double or triple
H_9 3835.39	0.00	Small	Insignificant asymmetry V
H_8 3889.07	+0.13	0?	Small asymmetry V

Remarks. H_{16}. The division is due to V 3703.59, E. P. 0.299. H_{15}. There are no lines for sensible influence. H_{14}. The strong weakening and the anomaly in the width are due to 7 faint Fe lines near the centre and to the wings of the distant but very strong lines Fe 3720.0, E. P. 0.000 and the blend 3722.6. H_{13}. In the solar spectrum very strong line Fe 3734.88, E. P. 0.855 is observed, which might be supposed to have an appreciable effect. But in M stars this line seems to be somewhat fainter and the small weakening of H_{13} is probably justified. H_{12}. Evidently a very sensible influence of the strong line Fe 3749.50, E. P. 0.911. H_{11}. There are no lines for sensible influence. According to Merrill, sometimes double. This is probably due to a faint blend 3770.5 observed in M stars. H_{10}. The faint absorption lines near the centre cause probably the doubling (according to Adams, H_{10} is a triplet). The influence of the low-temperature blend 3798.3 seems to be sensible. H_9. A very small influence is possible only from Fe 3834.23, E. P. 966. H_8. Double according to Adams (possibly, owing to the faint line Fe 3888.83). When comparing the wave-lengths, it is uecessary to allow for the relative shift of the emission lines (about—0.2 Å).

As to the low members of H, it is preferable to use the data obtained with high dispersion. According to the older data, the structure of Hδ and Hγ is composite. The best modern observations show these lines to be only double, and the comments by Adams may be interpreted to some extent as an indication that this doubling is due to hydrogen absorption lines. In this connexion it is of interest to note a very considerable negative displacement for Hα in Me stars (Shane—1.0, Merrill's modern result—0.4 Å). We think that this is due to the influence of an absorption line Hα (see below).

Comparing now the numerous data, we must conclude that the extreme non-uniformity of hydrogen emission lines with respect to the structure, the intensity and the anomaly in the wave-lengths may be explained, at least in the majority of cases, without serious exceptions in terms of the hypothesis of overlying absorption, the absorbing material being not only TiO and Ca II but also V I, Fe I, Cr I, H. In my paper on the emission Fe II lines the absorbing material was found to be TiO, Fe I and Ca I ([3]). This result seems to be an extension of that found previously with respect to this point [Merrill, Shane([4])].

3. The question of self-absorption is of interest, since when considering it in the light of the theory of the curve of growth one may hope to derive the number of hydrogen atoms. It seems to be evident at once that the lines Hα and Hβ must be excluded, since the predominant rôle in the weakening belongs here to TiO. Attention must be paid to the observed fact that the emission lines Hβ and Hα are sometimes not seen at all, while the continuous background is quite perceptible here. One may show that whatever the effective level of emission material with respect to TiO may be and whatever the mechanism of the decrease of intensity, the weakening for the continuous background cannot be less than that for the emission lines. Absolutely the emission line may strongly decrease in intensity, but the total intensity expressed in units of the continuous background cannot decrease. In fact this does not hold, at least sometimes for Hβ and Hα, and for this reason any additional absorption for these lines may be suggested. One may think here of a self-absorption properly said and of a decrease of radiation flowing through overlying layers which contain the absorbing hydrogen atoms. We think, though this is possibly in disagreement with the adopted

opinion, that absorption hydrogen lines are perceptible in the spectra Me. It is true, the theory predicts at temperature of about 3000° a negligible percentage of hydrogen atoms in the second quantum state. As a matter of fact, the hydrogen absorption lines in gM_5—and especially in cM_5— are exceptionally strong. This anomaly may be partly connected with the very low value for $g_{eff.}$ and with the great extension of the atmosphere. This is probably also of importance for Me stars. It is to be noted that when T and g are low, the Balmer decrement for absorption lines must be considerable. Therefore, if even Hδ and Hγ are faint, the absorption line Hα may be still strong enough.

The following arguments are brought in favour of the presence of hydrogen absorption lines in the spectra Me: 1) Systematic displacement (about—0.4.Å) for Hα in emission, which apparently is very difficult to explain otherwise than by the influence of an absorption component Hα. 2) According to Joy (5), near the epoch of Min., when the emission hydrogen lines disappear, hydrogen is observed in absorption. 3) Some possibility of the interpretation of the doubling of Hδ and Hγ as an effect of corresponding absorption lines of H. 4) Some analogy between the absorption spectra of Me and gM—cM.

The presence of hydrogen absorption lines seems to be much less probable in Se and still less so in Ne stars.

The probability of the presence of absorbing hydrogen atoms in Me represents in itself an interesting fact. But in connexion with this it is very difficult to draw some conclusion with respect to the self-absorption properly said. It seems to be probable that both effects are present: in favour of the former speaks the observed systematic displacement—0.4 Å for Hα and other facts; in favour of the self-absorption, the probable weakening of Hα in Ne and Se. However, from the point of view of the study of the self-absorption it is worthy to pay attention to the violet region. It was already mentioned that the anomalies within H_6—H_{16} find a satisfactory explanation and that the Balmer decrement here is more or less «normal», say, as in Be stars or in the chromosphere. This points to an emission under conditions of an optically thin layer

$$\left(A\lambda = \frac{\pi e^2}{mc^2}\lambda^2 \cdot 10^8 \cdot NHf\right)$$

But the most interesting fact is that in addition to the «normal» decrement the observed total intensities of high Balmer members are considerable. This is seen at once, since while the line width is of the order 0.6 Å, the contrast between such lines as H_{11} and the continuous background is high. Our measurements gave E. W.$\geqslant$1.0 Å for Hζ and even for H_{11}. It is evident that the accuracy of such measurements may be only low. For the case of an optically thick uniform layer the total intensity is expressed by

$$E = B\int_0^\infty (1 - e^{-NHf})\, d\lambda$$

In the general case B may be considered as the mean intensity of exciting radiation, which may be found from the study of the profile of the spectral line. In the case of thermal equilibrium $B\lambda$ is Kirchhof-Planck's function for T_0 (according to the theory of radiative equilibrium, the intensity of radiation from the limb). Therefore, expressing the measured E in units of intensity of the continuous background (reducing the latter to the value for the limb) we obtain E/B (in our case here is evidently presumed the thermal equilibrium for T_0 of the order of 2700°). The integral $\int_0^\infty (1 - e^{-NHf})\, d\lambda$ was discussed in detail in the theory of the curve of growth for the absorption lines, and these results may be applied immediately to the measured values E/B for the emission lines. Turning now to the curve of growth connecting $\log \frac{NHf}{\Delta\omega_D}$ with $\log \frac{E}{B2\Delta\omega_D}$, one may see

that at given E the less is $B2\ \Delta\omega_D$, the stronger is the self-absorption. The lower is the temperature, the earlier will take place a transition from the 45° branch into the intermediate one of the curve of growth. In the application of these reasonings to the Balmer lines it is supposed that the portion of the spectrum under consideration is very limited. At $T = 3000°$ the self-absorption must be still appreciable for E. W. about 0.50 Å, and therefore in our case for Hζ and even for the higher members. However, as this was mentioned earlier, the conditions of the optically thin layer hold at least as far as Hδ. The explanation must be probably looked for in that the value $2\Delta\omega_D B$ is in fact much higher than $2\Delta\omega_D \times$ Kirchhof-Planck's function for T of the order of 2700°. One may think here of some analogy with the phenomenon of «turbulence» recently discovered by Struve and Elvey (7) in the rare objects of early class. In the latter case the cause is to be looked for probably in the large macroscopic movements greatly increasing the value $\Delta\lambda_D$. But in the case of emission lines the transition into the intermediate branch of the curve of growth will depend on the function $B2\Delta\omega_D$. The observed width of the emission lines H of the order of 0.6 Å does not still predestine the predominant rôle of the macroscopic movements. It will be shown elsewhere that the large width of the emission lines H is partly due probably to the outward motion of gases. The main cause of the «normal» decrement in Me is probably in that the exciting radiation for the emission spectrum is much stronger than that corresponding to the thermal equilibrium for T of the order of 2700°, if one may think at all of the formation in any way of the emission lines at such a low temperature. One may bring several arguments in favour of the suggestion that in Me stars the absorption and the emission spectra are generally independent, and that the origin of either are due to different physical processes and conditions. Here we have found in the behaviour of the Balmer decrement an evidence that the emission spectrum in Me stars is properly not connected with the photospheric radiation, determining mainly the temperature of atmospheric layers and the general character of the absorption spectrum. This result is in agreement with the difficulty, it seems, to represent the appearance of the emission lines in the ordinary conditions at low temperature, especially of lines of such high excitation as H and Fe II.

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HEAT ENGINEERING

THERMAL REGIME OF BURNING AND GASIFICATION OF A LAYER OF SOLID FUEL

By Z. F. CHUKHANOV, Corresponding Member of the Academy

1. For a given variety of solid fuel the technical possibility and expediency of its combustion or gasification, as well as the choice of the adequate method for carrying out this process is essentially determined by the temperature field set up during the burning. The thermal regime, or, more precisely, the maximum temperature of the surface is a particularly important factor when local low-grade fuels high in ash are burned.

Theoretically, as well as experimentally, the study of the thermal regime of burning is a matter of considerable difficulty. When analysing the thermal conditions created by the combustion of a solid layer or an aerosuspension, the ordinary method of investigation which is to represent a layer of particles as an averaged isotropic body, cannot possibly be used because the variation of the surface temperature of the solid particles in the presence of a temperature gradient along the layer, which is essentially a heat exchange process, bears a pronouncedly step-like character. The curve of the surface temperature variation in the particles along the layer shows ruptures on passing from one particle to the next. To represent the temperature field in the burning layer as analogous to that in an isotropic body is not merely quantitatively incorrect (even as an average), but by doing so we also obscure the very essence of processes taking place in the layer, in so far as their mechanism is thereby concealed in the so-called «constants of total heat conductivity» which vary with temperature and with the size of the particle, and depend moreover on the conditions under which the layer is working.

All attempts to employ this method in the analysis of a heated and burning layer have failed to secure an adequate and clear-cut interpretation of the influence of the various factors on the thermal regime, although more than one thorough investigation has been carried along this line ([1], [2]). In one of his earlier papers the author ([3]) while discussing the qualitative side of the problem was able to state that the thermal regime of burning and gasification is to a great measure under the influence of the so-called «outlet of heat» along the layer. It is an easy matter to show that the rôle of the heat outlet becomes decisive when the evolution of heat Q_0 in the oxygen zone per 1 kg of consumed fuel is a constant quantity.

Let us consider the scheme of the burning process in a layer of fuel in the case of limited inflammation (Fig. 1). When the blowing and coke are delivered at 0°C the equation of heat balance in the oxygen zone for 1 kg of consumed coke can be written as follows *:

* The loss of heat across the walls of the apparatus is not taken into account, first because its relative magnitude in industrial apparatus is not usually very significant and, secondly, because its influence is confined to the burning region near the wall.

$$Q_0 = Q_{gas} + Q_t + Q_k \qquad (a)$$

where Q_{gas} is the physical heat carried off from the oxygen zone by the amount of gas obtained from 1 kg of coke; Q_t is the heat let out or, in other words, transferred from the oxygen zone to the reduction zone by conduction and radiation; Q_k is the physical heat carried off from the oxygen zone with the coke-ash residue.

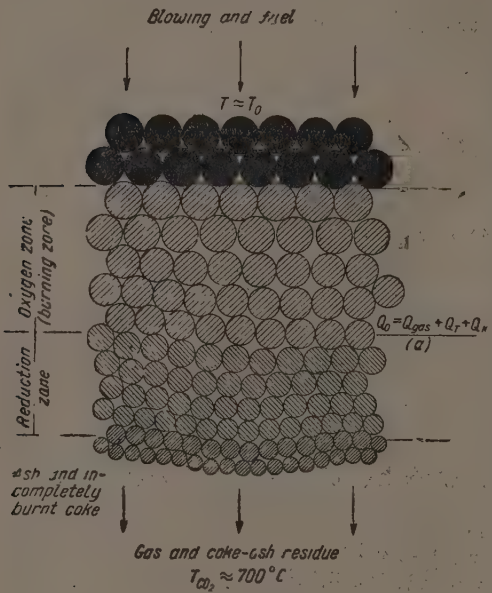

Fig. 1

Experiments ([4–8]) have shown that under such conditions as are usual for the operation of the industrial apparatus fed with solid fuel, a constant Q_0 means that at the end of the oxygen zone ($O_2 \cong \cong 1\%$) CO_2 is formed practically alone.

The process of interaction between carbon and oxygen proceeds, according to the bireaction theory put forward by the author ([8]), with the formation of primary carbon oxide. This result is obtained whether the process is an «oxidation» reaction $4C + 3O_2 = 2CO + 2CO_2$ ranging in order with respect to oxygen from zero to one, or a «carbon burn out» reaction $2C + O_2 \rightarrow 2CO$, which according to the refined data of the author (with allowance for the burning-out of particles in the layer) is of order one with respect to oxygen. It follows from this that under any conditions (even with low concentrations of O_2) there is a certain amount of primary carbon oxide on the surface of the carbon. However, with the low rate of blowing ([4–8]) characteristic of the work of industrial apparatus, both the primary and secondary carbon oxide $[CO_2 + C + (O_2) = 2CO + (O_2)]$ is practically burnt to the end in the oxygen zone.

This is confirmed by the data the author has obtained on the kinetics of carbon oxide burning.[1]

In this case, *i. e.* with $Q_0 = \text{const}$, neither Q_k nor Q_{gas} will depend upon the external conditions such as the work of the reduction zone, the size of a coke lump, the rate of blowing, and whenever Q_t is constant, these two quantities will be constant, too.

If, therefore, the composition of the blowing and coke is constant, the only term in equation (a) that may be influenced and controlled is Q_t. Hence it is through this term alone that the thermal regime in a burning layer of solid fuel can be controlled to some measure when Q_0 is given.

Just what is the mechanism of the heat outlet and by what measures can its rôle in the process be modified, thus permitting of a control over the temperature field created by the burning?

The simplest case of heat outlet is when the latter alone determines the temperature field at the surface of the particles between some given T_1 and T_s. This case is possible if the heat outlet is confined to two rows of particles of the bur-

ning fuel, or if the evolution of heat at the surface of every intermediate * row is equal to the sum $Q_{gas} + Q_k$.

Let us consider this case (Fig. 2, *a*) which is analogous to the thermal conductivity of a layer of particles in a vacuum. When a point is the site of contact between the particles, the layer practically lets no heat to pass through by conduction.

Experimentally this fact has been confirmed in a very illustrative manner by E. A. Shapatina in the author's laboratory at the Power Research Institute. A layer of particles, including metallic particles, *in vacuo* is a good heat insulator.

Therefore the transfer of heat along the layer (z-axis) from particle to particle is only possible by radiation, while across the particle heat is transferred by conduction.

Under the conditions of Fig. 2, *a* ($T_1 > T_5$) heat is transferred from the first row of particles to the second by radiation. The temperature distribution in the particles of the second row is defined by the Fourier equation for a stationary

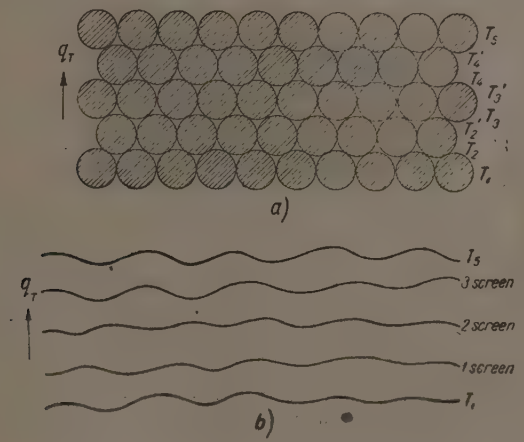

Fig. 2

regime under corresponding boundary conditions. To the third row of particles heat is again transferred by radiation, and its way across the particles making up this row is by conduction, and so on up to the fifth layer.

Without undertaking to solve analytically the very complicated problem of an accurate determination of q_T, one can easily show by solving approximately a few numerical examples** that with the size of coal lumps as used in practice (~20—30 mm) and with the customary working stress of the process a mean temperature difference ($T_2 - T_2'$) of several hundred degrees will be required for no more than 15 per cent of the heat evolved in the burning zone to be transferred through only one layer of particles.

It will be obvious that if the particles of a layer of fuel have the size customarily applied in practice, the heat outlet through more than one row of particles cannot possibly be very large and is mainly restricted to the first row of the reduction zone to which heat is transferred by radiation from the last row of the oxidation zone. This heat is absorbed intensively in the endothermal reac-

* The process is looked upon as stationary in the mean without making allowance for the period of transition from one row to the next, as new rows of particles come to be involved in the burning process.

** Supposing the layer to be a gas-tight partition of a thickness varying according to the size of particles, applying Fourier equation and using tabulated values of λ.

tions that give rise to the producer gas, which explains why in an ordinary gas producer the rate of growth of the concentration of CO is particularly high in this part of the reduction zone.

The larger the size of the coal lumps and the smaller their heat conductivity λ, the less is the value of the heat flow q_T in the layer, represented in Fig. 2. If we shall decrease the size of the particles in the layer (Fig. 2), the heat flow will grow and the temperature gradient in the individual particle will diminish. Clearly, in the limit, *i. e.* for very small particles of fuel, we shall have $T_2=T'_2$; $T_3=T'_3$; $T_4=T'_4$, that is all particles throughout the volume will have a practically equal temperature.

In such a case the heat flow q_T from the first row of particles to the fifth (Fig. 2) will not depend upon the thermal conductivity of the particles, and to all practical purposes will be determined accurately enough from the quantity of heat transferred by radiation from row to row. Our problem in this case is reduced to the well-known problem of heat radiation through a system of screens. The quantity of transferred heat is here defined by the relation

$$q_T = Q_p = \frac{F_s C_{pr}}{q_0+1}\left\{\left(\frac{T_1}{100}\right)^4-\left(\frac{T_5}{100}\right)^4\right\} \qquad (1)$$

where q_0 is the number of screens in the system; F_s, the area of the radiating (receiving) surface of a partial row (screen); $C_{pr}=\frac{1}{2/C-1/C_a}$, and C and C_a are the radiation coefficients of the particles' material and of an absolutely black body, respectively. If the layer is a random arrangement of spherical particles, or, especially, of particles of no definite form, consisting of coke or some other material, then those of them referring to a given screen are not necessarily lying between two parallel planes separated by a distance d from each other. The individual particles of a screen as well as the entire screens can in this case be pushed farther apart in space, unless the medium that separates them absorbs radiation to an appreciable extent.

Fig. 2, *b* is a scheme of such a set of screens substituted for the rows of particles in a layer. This scheme, as follows from our analysis, is a physically real «average model» of the phenomenon of heat outlet along a layer of small solid particles.

Under the conditions of Fig. 2 the magnitude of the heat flow grows with the decrease of the particle size approaching asymptotically the limit defined by the equation (1) *. The character of the variation of q_T with the particle size is affected by the material of which the particles are made and by the values of T_1 and T_5 (Fig. 2).

Reverting now to the real layer of burning particles (Fig. 1), let us see how far our model for heat outlet applies in this more involved case.

While in the case of Fig. 2 no heat carried away by conduction and radiation is consumed until the fifth row of particles has been reached, the expenditure or evolution of heat in a real burning layer takes place at each of the screens. It is only natural then that the character of the temperature field created in a system of screens by the combined action of the «sources» and the outlet of heat is affected also by the heat exchange due to convection. Unmodified remains the fundamental condition that upon the burning of a layer of small particles—even as in the case of a simple transfer of heat through a layer—the temperature within an individual particle is practically invariable throughout its volume and the isothermal surfaces crossing the particles of equal temperature

* The value of F_s in (1) should be near to 1.5 m² per square metre area of the cross-section of the apparatus. But the precise value depends upon the form and the arrangement of the particles in the layer and has to be refined by experiment. Here and later the cross-section of the layer is taken to be large in comparison with the particle's cross-section.

behave as receiving and radiating screens. Thus, in principle our «model» of heat exchange is also applicable * in the case of a burning layer with a qualification that the «heat outlet» determining the temperature field in a burning layer should be computed separately for each «screen».

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* Naturally enough, under practical conditions there will be no strict equality of temperature between the different particles of a screen or of an isothermal surface because of the differences in the form arrangement and position at a given instant. A burning layer is «breathing» continuously—the position of its particles is subject to continual variation, and therefore our isothermal surfaces must be looked upon as furnishing a statistically averaged scheme of the process.

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GEOPHYSICS

ON INTERPRETATION OF REFRACTION WAVE ISOTIME MAPS

By G. A. GAMBURZEV

(Communicated by O. J. Schmidt, Member of the Academy, 20.XII.1943)

In one of his previous papers (1) the author pointed out the features that basically characterize the use of isotime maps in prospecting according to the correlation refraction method. Below, without going into detail, there will be described an approximate method of spatial interpretation of isotime maps.

This method has developed from the same circle of ideas as lie at the basis of the method of «time fields» suggested by Risnichenko (2). The difference is that instead of constructing the time field itself, only such its sections, or their projections, are plotted which permit a given three-dimensional problem to be replaced by a set of elementary two-dimensional ones.

Let us take the case of a single refracting boundary that divides two isotropic and homogeneous media. This division boundary is supposed to have a relief undisturbed to such an extent that the travel time curves of the reflected waves have no singular points. The values of seismic velocities (a_1 and a_2) to either side of the boundary are known; in the lower layer the velocity is higher than in the upper. The time field in the lower layer is given, and the wave fronts are assumed to have the shape of vertical cylinders.

What we have to determine, is the configuration and position of the refracting boundary on the isotime map.

Thus formulated the problem admits of an exact solution which has besides the advantage of being convenient practically. We shall consider in the isotime map an arbitrary line s. To this line there will correspond a striated surface S formed by those seismic rays in the upper layer which cross the line s. The shape of this surface is fully determined by the values of vector G on line s, this vector representing the gradient of the time field in the upper layer. The azimuth of this vector coincides with that of the normals to the isotime curves in the plane of observation at points lying on the line s, and its inclination to the vertical can be found from the well-known formula of Benndorf.

The wave fronts in the upper layer intersect the surface S along a system of isotime curves which will be described by the name of S isotime curves. We project these curves on the plane of observation (A). For this purpose we select a number of points on the line s (those marking the intersections of this line with the observed isotime curves are the most convenient from the constructional point of view) and for each of them we plot normals n to the respective isotime curve in the plane A. Each of the normals we cut up into segments as long as $a_1 \Delta t \sin i = a_1^2 \Delta t \frac{dt}{dn}$ where Δt is the adopted interval of time between neighbouring isotime curves; i is the angle of the ray with the

vertical in the first layer; dt/dn is the gradient of the surface travel time curve in plane A.

The projections of S isotime curves on to the plane A should pass through the ends of these segments. To these curves we shall arbitrarily assign the name of S_A isotime curves. It is assumed while constructing them that the boundary B is absent.

Together with the family of isotime curves S_A we shall consider a family of projections on to plane A of isotime curves at the boundary B. These lines will be described arbitrarily as B_A isotime curves. Although the shape of the boundary B is unknown, we are still able to build the B_A curves, because neither their position nor shape depend upon the vertical in the lower layer.

Upon the exit of seismic waves from the lower medium into the upper the time field apparently suffers no rupture. This may be taken to mean that the division boundary B of the isotime curve B must intersect with the respective S lines of the same index. At the intersection points is the origin of the rays (first layer) whose ends lie on the line s. If we project a pair of similarly indexed isotime curves B and S on to plane A, we shall find the similarly indexed isotime curves B_A and S_A to intersect at a point which is the projection of the intersection point of the given pair of isotime curves B and S. The same is true of any other pair B_A and S_A similarly indexed.

The locus of the intersection points of B_A and S_A forms a line f on the plane A. On this line are lying the projections of the exit points from the lower to upper medium for all rays crossing the plane A along line s. The distance between the lines s and f measured in the direction of the gradient of the surface travel-time curve at points lying on s is equal in length (L) to the projections on to plane A of the respective seismic rays in the first layer.

Knowing L, we find for the depth of the boundary B, as measured from the line f along the vertical, the expression $H = L \operatorname{ctg} i$. Similar operations carried out for several other sections of the isotime map will afford the possibility upon comparing the results obtained to derive from the isotime map a map of the refracting boundary in isodepths.

If the time field in the lower layer is given up to a constant, the problem has no unique solution any longer, and a whole family of possible solutions can be constructed in this case. Practically, however, the number of variant solutions can be made rather small by suitable choice. This is possible on account of the good stability of the solution with respect to the shape of the refracting boundary.

If the depth of the refracting boundary at some point of the isotime map is known, the uniqueness of the solution can be restored.

The method is also applicable when there are several division boundaries. To be able to build an $(n+1)$-th boundary, we have to know the form and position of the n preceding boundaries. The procedure whereby we obtain the solution remains unaltered. In fact, by transferring the observed surface travel time curve to the last known boundary the problem is reduced to the case of one boundary.

Then the surface travel-time curve observed will no longer refer to a plane boundary; still we shall not encounter any substantial difficulties in determining the surface S, though the process of getting at the solution becomes somewhat more involved. As before, the isotime curves S and B have to be projected on the horizontal plane. Thus, having an isotime map of refracted waves for each division boundary separately, we are able, following the determination of the first boundary, to determine the second, the third and so on.

Let us schematically discuss the question as to the practical value of the method suggested here.

Under conditions formulated at the beginning of this article our problem in the case of one or more than one layer has an exact solution. The most serious assumption is that the time field in the lower layer is given and the wave fronts in the lower medium (at the boundary) have the form of vertical cylinders. The

verticality requirement can be got rid of by substituting the orthogonal projections with non-orthogonal, but at any rate the form of the cylinders must be given beforehand.

In practice, however, this requirement is often not at all inconvenient. If, for instance, the division boundary is a convex shape and its depth in the zone of explosion and in that of observation is approximately equal, then the true wave fronts near the points of exit of the wave from the lower to the upper medium will deviate very little from vertical circular coaxial cylinders, having their axis crossing the shot point. In the general case the position and form of the wave fronts in the lower layer cannot possibly be set beforehand. And this is especially true of their inclination to the vertical, because it is subject to considerable variation depending upon the form of the boundary which we have to determine. However, the solution is practically very little affected by the possible variations of the inclination angle of the wave front in the lower layer, except when the boundary has a wide inclination and the seismic velocity differences are small. As for the absolute time marks of the wave fronts and their form in the horizontal section, they depend little upon the shape of the boundary in the observation zone, so that in building up the wave fronts in the lower layer the boundary may be assumed to be plane. The depth of this plane remains indeterminate, and one may be compelled to look for variant solutions, as pointed out above.

The indeterminacy in constructing wave surfaces can be lessened to a great extent if we have in the research area several «calibrating» radial counter-profiles (directed to the shot point adopted in areal prospecting).

It will be obvious that our main condition can be approximately satisfied and so the method described here may be looked upon as fitted to put an approximate interpretation on the isotime maps of refracted waves.

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CHEMISTRY

ON SOME STERIC HINDRANCES INVOLVED IN THE FORMATION OF COMPLEX COMPOUNDS WITH COMPLEX AMINES

By A. M. RUBINSTEIN

(Communicated by I. I. Černjaiev, Member of the Academy, 29.II.1944)

The study of the reaction in which 5I2AmPy interacts with K_2PtCl_4 has revealed that when potassium chloroplatinite is acted upon by iodo-aminopyridine a compound of the composition $(2Am5IPy)_2Cl_2Pt$, having a trans-configuration, is formed. This result is of interest as the first recorded case of a trans-salt obtained through the action of pyridine derivatives upon salts of divalent platinum.

In acting upon potassium chloroplatinite with amines (exclusive of thiourea, ethylene and its analogues) we, in accordance with the Peyronet law, always obtain a cis-configuration compound A_2X_2Pt, which may easily be accounted for in terms of the trans-influence theory put forward by I. I. Černjaiev.

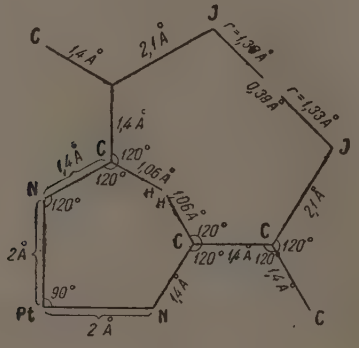
Our case is therefore an exception to the Peyronet law. To explain it we may advance two possible reasons: 1) a trans-configuration compound is formed because the bond between iodo-aminopyridine and platinum is effected not through tertiary nitrogen, but through iodine; 2) the bond is through tertiary nitrogen, but steric hindrances stand in the way of the formation of a cis-configuration compound.

The bond between iodine and platinum may be created by a strong polarizing action of iodine. That iodine may indeed exert such an action becomes apparent, if we take into consideration that the covalent radius of the iodine atom is 1.33 Å and that of the platinum atom 1.31 Å. If the linkage of platinum with iodo-aminopyridine is through the iodine atom, then the molecule of iodo-amino pyridine must change its orientation with the result that a trans-configuration compound is formed.

As a confirmation of this way of linkage the author may refer to the reaction between pyridine and $(2Am5IPy)_2Cl_2Pt$ which he has investigated to find that the halogen substituted aminopyridine is rather easily displaced by another amine (pyridine). When pyridine is made to act upon the aminopyridine dichloride of platinum $(AmPy)_2Cl_2Pt$, in which the aminopyridine is linked with platinum through tertiary nitrogen, the reaction proceeds with the formation of a mixed tetramine $(AmPy)_2Py_2PtCl_2$, and no displacement of aminopyridine by pyridine is observed. Not so in our case, where pyridine acts upon $(2Am5IPy)_2Cl_2Pt$. Here iodine binds platinum to iodo-aminopyridine, and this bond is so weak as to permit pyridine to displace iodo-aminopyridine from the inner sphere, whereby dipyridine dichloride of platinum is formed in trans-form.

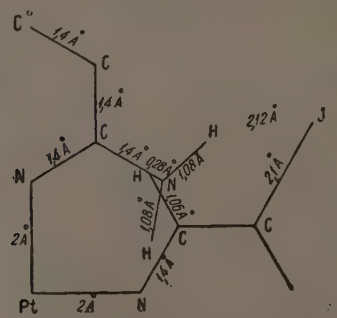
In order to show the possibility of a trans-salt being the result of steric hindrances, we shall consider some cases where no steric hindrance prevents the formation of $(2Am5IPy)_2Cl_2Pt$ in the cis-form. If we conceive the molecules of

iodo-aminopyridine as lying in one plane and turned to each other with their iodine atoms, it will be possible to prove by calculation that such configuration is impossible sterically on the ground that the distance between the hydrogen atoms of the pyridine ring, as well as that between the iodine atoms is so small as to give rise to a strong repelling action between the respective atoms, which fact will bring about the formation of a trans-compound.

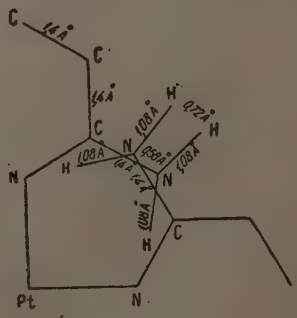


The above scheme is the result of the author's calculation of steric possibilities for the formation of the cis-form of $(2Am5IPy)_2Cl_2Pt$ when the two molecules of the iodo-aminopyridine have their iodine atoms facing each other. In this calculation data on interatomic distances were used, as determined by several different authors mainly from spectroscopic and electronographic investigations.

In this scheme the distance between the hydrogen atoms is seen to be as small as 0.12 Å. In a hydrogen molecule, which may serve here as an example of the



(a)



(b)

densest packing, the hydrogen atoms are as far between as 0.74 Å. The distance between two iodine atoms in our case is 0.39 Å. So the atoms of hydrogen as well as those of iodine are located close to each other, with the result that a strong repelling force will interpose itself as a serious obstacle to the formation of a cis-compound.

One may imagine that one aminopyridine molecule has its amino-group facing the iodine atom of the other molecule, but it is possible to show that this con-

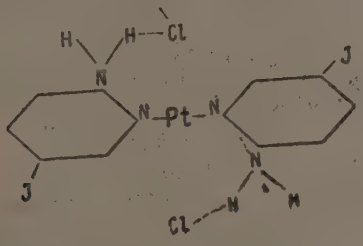
figuration is disadvantageous sterically. The results of the author's calculations to this effect are shown in another scheme (*a*).

In this scheme the distance between nitrogen and hydrogen is only 0.28 Å, as against 1.01 Å which last is the least distance between these atoms necessary for the formation of a bond. The distance between iodine and hydrogen is 2.12 Å. It is obvious from this calculation that this second configuration is likewise unprofitable from the steric point of view.

It remains to consider the case where the two iodo-aminopyridine molecules are turned to each other with their amino-groups. This configuration has also been computed by the author and the results are shown in the third scheme (*b*).

The distance between the nitrogen of one amino-group and that of the other group is seen to be 0.58 Å. This is much less than the least distance between two nitrogen atoms in a molecule of nitrogen, which is as great as 1.2 Å. The distance between the hydrogen atoms is 0.72 Å as against 0.74 Å, the distance between the atoms in a hydrogen molecule. It will be apparent that such a configuration is impossible sterically, because it implies the presence of a strong repelling force between the nitrogen atoms of the amino-groups and between the hydrogen atoms.

The steric hindrances discussed in these paper are thus responsible for the formation of $(A2m5IPy)_2Cl_2Pt$ as a trans- and not as a cis-compound:



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PHYSICAL CHEMISTRY

THE CONCENTRATION OF H ATOMS IN A LOW-PRESSURE HYDROGEN FLAME

By W. W. WOJEWODSKY

(Communicated by N. N. Semenov, Member of the Academy, 4.I.1944)

From the chain mechanism advanced by Lewis and Elbe (1) to explain the phenomena observed in a low-pressure hydrogen flame one may determine the ratio of the concentrations of atomic hydrogen and hydroxyl in the flame:

$$\frac{(H)}{(OH)} = \frac{k_1}{2k_2}\frac{(H_2)}{(O_2)} \qquad (1)$$

where k_1 and k_2 are the rate constants of the processes:

$$OH + H_2 = H_2O + H \qquad (I)$$

$$H + O_2 = OH + O \qquad (II)$$

The concentration of hydroxyl in the flame may be determined experimentally.

The constant k_1 has been computed by Kondratjew (2) from data obtained by Avramenko (3) in a spectroscopic study of the hydrogen flame:

$$k_1 = 7 \cdot 10^{-12}\sqrt{T}\; e^{-10000/RT} \qquad (2)$$

Hence, to calculate the concentration of H atoms it is sufficient to determine k_2. This constant enters into the approximate expression for the second limit:

$$P_2 = kT\frac{2k_2}{k_3} \qquad (3)$$

where k is the Boltzmann constant and k_3 is the rate constant of the process:

$$H + O_2 + M = HO_2 + M \qquad (III)$$

[The approximation made in deriving formula (3) consists in disregarding the influence of the rupture of chains on the wall].

If to determine k_2 we make use of formula (3), then taking the «energy of activation» Ep_2 determining the temperature course of the second limit to be equal to 25 000 cal. [the mean of experimental data (4)], $E_3 = 0$, the steric factor of process II $F_H = 1$ and τ, the life time of the quasimolecule HO_2, to be independent of the temperature, we get:

$$k_2 = 5 \cdot 10^{-11}\sqrt{T}\; e^{-24000/RT} \qquad (4)$$

Whence (at $T = 1000°K$) there is obtained for a stoicheiometric mixture [2]

$$\frac{(H)}{(OH)} = 150 \qquad (1')$$

and since at this temperature and at a pressure $P = 10$ mm Hg, the value of P_{OH}, according to spectroscopic data, is of the order of 10^{-2} mm Hg, then the pressure of atomic hydrogen calculated by formula (1') is found to be of the order of 1 mm.

Such large values of P_H put in question the soundness of the assumptions made in calculating this quantity.

And indeed, from the mechanism proposed by Lewis and Elbe [1] there is obtained the following general equation determining the limits of inflammation:

$$\left(\frac{P}{kT}\right)^2 - \frac{2k_2}{k_3}\left(\frac{P}{kT}\right) + \frac{k_H}{k_3 f_{O_2}} = 0. \qquad (A)$$

where k_H is the constant for the rupture of hydrogen atoms on the wall, dependent upon the pressure, temperature, and diameter and shape of the vessel, and $f_{O_2} = P_{O_2}/P$.

The roots of equation (A) will be the analytical expression of the lower and upper limits:

$$P_2 = kT\frac{k_2}{k_3}(1 + \sqrt{1-\Delta}) \qquad (5)$$

$$P_1 = kT\frac{k_2}{k_3}(1 - \sqrt{1-\Delta}) \qquad (6)$$

where $\Delta = \frac{k_H k_3}{k_2^2 f_{O_2}}$.

With a decrease in temperature, *i. e.* as we approach the tip of the inflammation peninsula, the difference $P_2 - P_1$ which, in accordance with expressions (5) and (6), is equal to

$$P_2 - P_1 = 2kT\frac{k_2}{k_3}\sqrt{1-\Delta}$$

should tend towards zero. Whence it follows that the condition determining the position of the tip is the equality

$$\Delta = 1 \qquad (7)$$

and, consequently, the pressure corresponding to the tip of the inflammation peninsula is:

$$p_M = kT\frac{k_2}{k_3}. \qquad (8)$$

From this expression it follows that the minimum temperature ($T = T_M$) of a low-pressure flame (in itself dependent upon the properties of the vessel) uniquely determines the magnitude of the corresponding pressure P_M for a given mixture composition*.

We shall show that this result is corroborated by all experimental data without exception relating to the inflammation limits of the hydrogen-oxygen mixtures.

In the table there are given all values of P_M and T_M for a stoicheiometric mixture available in the literature, together with a characteristic of the reaction vessel; in the accompanying figure these data are plotted in the coordinates $\lg P_M - \frac{1}{T_M}$.

* The composition of the mixture affects the value of k_3 (see below).

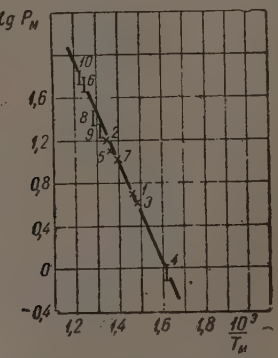
P_M (in mm Hg)	T_M (°C)	Material of reaction vessel and treatment	Diameter (in cm)	Authors
5	411	Pyrex treated with a large quantity of KCl	10	(5)
16	469	Pyrex treated with a large quantity of KCl	3.9	(5)
4	400	Pyrex treated with a small quantity of KCl	7.4	(5)
1—0.8	340	Pyrex treated with $K_2B_4O_7$	7.4	(5)
11.9	461	Quartz	1.8	(6)
50—60	532	Iron	2.6	(7)
11	442	Glass		(8)
22—27*	500	Pyrex treated with KCl	2	(4)
15—21*	480	Pyrex treated with KCl	2	(4)
58—64*	570	Pyrex treated with KCl	2	(4)

* In the experiments of Frost and Alyea[4] the tip was determined at the given temperature by the change in composition of the $H_2:O_2$ mixture. According to Lewis and Elbe[1] the composition of the mixture affects the value of k_3 as follows:

$$k_3 = k_3^{H_2}\frac{P_{H_2}}{P} + k_3^{O_2}\frac{P_{O_2}}{P}$$

The values of P_M given in the table have been recomputed for a stoicheiometric mixture on the basis of the relation $\frac{k_3^{O_2}}{k_3^{H_2}} = 0.35$(5).

As can be seen from the figure, all the given data lie, within the limits of



accuracy of experiment, on a straight line determining the energy of activation of the quantity $\frac{k_1}{k_{II}}$ which is found to be equal to

$$E_M = 21\,000 \text{ cal.} \qquad (9)$$

We shall show that this value is not inconsistent with the value $E_{P_2} = 25\,000$ cal. given above. To do this we will express P_2 in the form

$$P_2 = A_1 e^{-E_{P_2}/RT} = Be^{-E_M/RT}(1+\sqrt{1-\Delta}) \qquad (10)$$

and calculate the difference $E_{P_2} - E_M$.

It is easy to see that the quantity Δ may be represented as an approximation in the form of an exponential function.

And indeed, the approximate values of P_1 and P_2, which hold for $P_2 \gg P_1$, can, according to equation (A), be calculated from

$$P_2 = kT\frac{2k_2}{k_3} \text{ and } P_1 = kT\frac{k_H}{2k_2 f_{O_2}},$$

that is,

$$\Delta = \frac{4P_1}{P_2}.$$

Since, on the other hand, the quantities P_1 and P_2 have the form ([7],[9])

$$P_1 = a_1 e^{41000/RT} \text{ and } P_2 = a_2 e^{-25000/RT}$$

we obtain for the quantity Δ: $\Delta = \Delta_0 e^{-E_\Delta/RT}$ where $E_\Delta = 36\,000$ cal.

If we first take the logs of both expressions for P_2 given above (10) and then differentiate with respect to temperature, we get:

$$E_{P_2} = E_M + \alpha |E_\Delta|$$

where $\alpha = \frac{\Delta}{2(1-\Delta+\sqrt{1-\Delta})}$ varies from $+\infty$ when $\Delta = 1$ to 0 when $\Delta = 0$; that is, the difference $E_{P_2} - E_M$ is always greater than zero, since $1 \geqslant \Delta > 0$.

Hence the quantity E_{P_2} (calculated from the temperature course of the upper limit of inflammation P_2) should be greater than $E_M = 21000$ cal., which is in full agreement with experiment [the values of E_{P_2} obtained by different authors vary between 23 000 cal. and 30 000 cal. ([4])].

If we take τ to be independent of the temperature, $E_3 = 0$ and $F_H = 1$*, then from:

$$\frac{k_2}{k_3} = C\frac{\sqrt{T}}{T}e^{-(E_2-E_3)/RT} = \frac{B}{T}e^{-21000/RT}$$

we get $E_2 = 20\,000$ cal. In this case k_2 is found to be equal to

$$k_2 = 5 \cdot 10^{-11}\sqrt{T}\ e^{-20000/RT} \qquad (11)$$

which for a stoicheiometric mixture at $T = 1000°K$ gives:

$$\frac{(H)}{(OH)} = 13$$

Hence, under the conditions given above the concentration of atomic hydrogen is found to be of the order of one tenth of a mm of Hg.

However, the assumption that τ is independent of the temperature is also insufficiently exact. Thus, from Kimball's calculations ([11]) it follows that

$$\tau \sim 1/T^{n/2}$$

where n is the number of vibrational degrees of freedom taking part in the formation of a quasimolecule; in the case of HO_2 n is taken equal to 2, which leads to the following expression for k_3:

$$k_3 = \beta T\tau e^{-E_3/RT} = \beta' e^{-E_3/RT} \qquad (12)$$

Hence, employing the reasoning used above, we get $E_2 = 19\,000$ cal. and

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* I have shown that $F_H = 1$ is obtained from experimental data related to the lower limit of inflammation of hydrogen when these data are treated according to Academician Semenov's theory of the lower limit ([10]) generalized for the case of the rupture of two active centres (H and OH). The results of this investigation I communicated on Dec. 3, 1943 at a sitting of the scientific council of the Laboratory of Kinetics, Institute of Chemical Physics, Academy of Sciences of the USSR.

$$k_2 = 5 \cdot 10^{-11} \sqrt{T}\, e^{-19000/RT} \qquad (13)$$

which for a stoicheiometric mixture at 1000°K gives

$$\frac{(H)}{(OH)} = 8$$

i. e. in this case the concentration of atomic hydrogen in the flame at $T = 1000$°K and $P = 10$ mm Hg (a stoicheiometric mixture) is found to be approximately 10 times greater than the concentration of hydroxyl, *i. e.* of the order of 0.1 mm of Hg.

It is interesting to note that Elbe and Lewis ([5]) employing an independent method, arrived at the value 17 000 cal. for E_2.

A value of $E_2 = 18\,000$ cal. was also arrived at by Semenov ([12]) on the basis of recalculations of Kovalsky's data for the increase in the reaction rate of the oxidation of hydrogen within the inflammation peninsula in the neighbourhood of the lower limit.

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GEOCHEMISTRY

ON RUBIDIUM CONCENTRATION IN PLANTS. II

By T. BOROVICK-ROMANOVA

(Communicated by W. I. Vernadsky, Member of the Academy, 24.XII.1943)

The author has for the last three years been studying the content of rubidium in plants.

One of her earlier papers (1) contained data characterizing the concentration of this element in sea and fresh-water algae. The present article is dealing with rubidium concentration in land plants.

Table 1

Land Plants (Herbaceous Vegetation)

Family, genus and species	Place and date of collection	Rb content to ashes in %	Rb content to live weight, in %	Rb/K ratio
Compositae				
Centaurea jacea L.	St. Bolshevo, 1935	$2.7 \cdot 10^{-2}$	$5.6 \cdot 10^{-4}$	0.0015
Cirsium arvense Scop.	Zwenigorod, 1936	$0.96 \cdot 10^{-2}$	$2.2 \cdot 10^{-4}$	
Artemisia maritima L.	Bakress, 1936	$1.7 \cdot 10^{-2}$	$5.5 \cdot 10^{-4}$	
Inula britannica L.	Starosselje, 1936	$3.3 \cdot 10^{-2}$	$1.1 \cdot 10^{-3}$	
Gramineae				
Zea mays L.	» 1936	$3.2 \cdot 10^{-2}$	$6.0 \cdot 10^{-4}$	0.0014
Stipa capillata L.	St. Talovaya, 1936	$0.5 \cdot 10^{-2}$	$2 \cdot 10^{-4}$	
Leguminosae				
Trifolium pratense L.	Koshla Sala	$2.1 \cdot 10^{-2}$	$4.6 \cdot 10^{-4}$	
Lathyrus pratensis L.	Zwenigorod, 1936	$4 \cdot 10^{-2}$	$8.9 \cdot 10^{-4}$	
Polygonaceae				
Polygonum lapathifolium L.	Bolshevo, 1935	$5.1 \cdot 10^{-2}$	$1.2 \cdot 10^{-3}$	
» *persicaria* L.	Starosselje, 1936	$5.5 \cdot 10^{-2}$	$1.4 \cdot 10^{-3}$	0.0034
» *aviculare* L.	Bolshevo, 1935	$4.9 \cdot 10^{-2}$	$1 \cdot 10^{-3}$	
Ranunculaceae				
Thalictrum angustifolium Jacq.	Zwenigorod, 1936	$2.5 \cdot 10^{-2}$	$4.4 \cdot 10^{-4}$	
Thalictrum simplex L.	» 1936	$7.6 \cdot 10^{-2}$	$1.4 \cdot 10^{-3}$	
» *minus* L.	» 1936	$5.8 \cdot 10^{-2}$	$6.4 \cdot 10^{-4}$	
Pulsatilla patens Mill.	Right bank of Zola riv., 1936	$2.5 \cdot 10^{-2}$	$8 \cdot 10^{-4}$	
Chenopodiaceae				
Beta vulgaris L.	N. Caucasus, near Salsk	$2.9 \cdot 10^{-2}$	$9 \cdot 10^{-4}$	
Suaeda maritima Dum.	Do	Neglig. traces	Neglig. traces	

Continued

Family, genus and species	Place and date of collection	Rb content to ashes in %	Rb content to live weight, in %	Rb/K ratio
Salicornia herbacea L.	N. Caucasus, near Salsk	Negl. traces	Negl. traces	
Salsola soda L.	»	$0.13 \cdot 10^{-2}$	$6.4 \cdot 10^{-5}$	
» *Kali* L.	»	$0.56 \cdot 10^{-2}$	$2.6 \cdot 10^{-4}$	0.00018
Scrophulariaceae				
Euphrasia odontites L.	Starosselje, 1936	$8.9 \cdot 10^{-3}$	$1.8 \cdot 10^{-3}$	
Cannabineae				
Cannabis sativa L.	Koshla Sala, 1936	$3 \cdot 10^{-2}$	$5 \cdot 10^{-4}$	
Crassulaceae				
Sedum purpureum Lnk.	Zwenigorod, 1936	$4 \cdot 10^{-3}$	$3 \cdot 10^{-4}$	
Solanaceae				
Solanum nigrum L.	Starosselje, 1936	$7 \cdot 10^{-2}$	$2 \cdot 10^{-3}$	
Polypodiaceae				
Athyrium filix femina	Zwenigorod, 1936	$6.5 \cdot 10^{-2}$	$9 \cdot 10^{-4}$	
Aspidium (Dryopteris) filix mas. sw.	Gorkij region	$2 \cdot 10^{-2}$	$3.2 \cdot 10^{-4}$	
Polystichum Braunii	Near Mestia	$2.7 \cdot 10^{-2}$	$5.2 \cdot 10^{-4}$	
Lycopodiaceae				
Lycopodium clavatum L.	Koshla Sala, 1936	$5.5 \cdot 10^{-2}$	$5 \cdot 10^{-4}$	
Papaveraceae				
Chelidonium majus L.	Zwenigorod, 1936	$5 \cdot 10^{-2}$	$7 \cdot 10^{-4}$	
Geraniaceae				
Geranium transbaicalicus	Right bank of Zola river	$4.5 \cdot 10^{-2}$	$1 \cdot 10^{-3}$	

Table 2

Plants Growing on Marshes and along River Banks

Family, genus and species	Place and date of collection	Rb content to ashes, in %	Rb content to live weight, in %
Alismataceae			
Alisma Plantago L.	Starosselje, 1936	$3.9 \cdot 10^{-2}$	$9 \cdot 10^{-4}$
Umbelliferae			
Sium cicutifolium Gm.	Former bed of Zola river	$8 \cdot 10^{-2}$	$1 \cdot 10^{-3}$
» *latifolium* L.	Starosselje, 1936	$7 \cdot 10^{-2}$	$1 \cdot 10^{-3}$
Oenanthe Phellandrium Lam.	» 1936	$2.8 \cdot 10^{-2}$	$1.1 \cdot 10^{-3}$
Iridaceae			
Iris uniflorum Pull.	Gazimur works, 1936 (East Siberia)	$2 \cdot 10^{-2}$	$4 \cdot 10^{-4}$
Cyperaceae			
Scirpus lacustris L.	Starosselje, 1936	$2 \cdot 10^{-2}$	$3 \cdot 10^{-4}$
» *silvaticus* L.	Zwenigorod, 1936	$1.5 \cdot 10^{-2}$	$3 \cdot 10^{-4}$
Typhaceae			
Typha latifolia L.	Zwenigorod, 1936	$0.79 \cdot 10^{-2}$	$1.2 \cdot 10^{-4}$
Equisetaceae			
Equisetum limosum L.	Bolshevo, 1935	$2.5 \cdot 10^{-2}$	$5 \cdot 10^{-4}$
Halorrhagidaceae			
Myriophyllum spicatum L.	Kulindji river (East Siberia)	$1 \cdot 10^{-2}$	$1.8 \cdot 10^{-4}$
Gramineae			
Glyceria aquatica Whlb.	Starosselje, 1936	$3.3 \cdot 10^{-2}$	$1.1 \cdot 10^{-3}$

Literature furnishes some evidence as to the occurrence of rubidium in some land plants; no reliable quantitative determinations are, however, available. In order to fill up this gap the author determined the concentration of rubidium in 56 land plants. Among the herbaceous plants, representatives of the following families were analysed: *Gramineae*, *Leguminosae*, *Polygonaceae*, *Ranunculaceae*, *Compositae*, *Chenopodiaceae*, and some others; among the arborial plants the following families were taken for analysis: *Betulaceae*, *Pinaceae*, *Salicaceae*, *etc.* The concentration of rubidium in the plants was measured by the method of spectrum analysis. The procedure has been described in detail in our foregoing note (1).

The figures obtained are given in Tables 1, 2 and 3.

Table 3

Land Plants (Arboreal Vegetation)

Family, genus and species	Place and date of collection	Rb content to ashes, in %	Rb content to live weight, in %
Betulaceae			
Betula verrucosa Ehrh. (leaves)	Koshla Sala, 1936	$1.1 \cdot 10^{-2}$	$3.1 \cdot 10^{-4}$
» » » (roots)	» » 1936	$0.98 \cdot 10^{-2}$	$1.2 \cdot 10^{-4}$
» » » (trunk)	» » 1936	$1.1 \cdot 10^{-2}$	$1.0 \cdot 10^{-4}$
Betula nana L.	Vil. Zelentsy	$1.2 \cdot 10^{-2}$	$8.0 \cdot 10^{-5}$
Pinaceae			
Picea (trunk)	Peterhof, 1927	$2.6 \cdot 10^{-2}$	$1.1 \cdot 10^{-4}$
» (needles)	» 1927	$2.6 \cdot 10^{-2}$	$5.7 \cdot 10^{-4}$
» (roots)	» 1927	$2.8 \cdot 10^{-2}$	$1.4 \cdot 10^{-4}$
» (branches)	» 1927	$2.7 \cdot 10^{-2}$	$3.1 \cdot 10^{-4}$
Araucaria Brasiliana Lamb. .	Batumi, Botanical gardens, 1936	$3.4 \cdot 10^{-2}$	$6.2 \cdot 10^{-4}$
Salicaceae			
Salix glauca L. (leaves) . . .	Vil. Zelentsy	$4.5 \cdot 10^{-2}$	
» » » (stems) . . .	» »	$4.5 \cdot 10^{-2}$	
Leguminosae			
Acacia dealbata Lk.	Batumi, Botanical Gardens	$1.2 \cdot 10^{-2}$	$2.1 \cdot 10^{-4}$
Genista tinctoria L.	Starosselje, 1936	$4.6 \cdot 10^{-2}$	$4.4 \cdot 10^{-4}$
Theaceae			
Camellia japonica L.	Batumi, Botanical Gardens	$2.3 \cdot 10^{-2}$	$4.6 \cdot 10^{-4}$
Buxaceae			
Buxus sempervirens L.	Batumi, Botanical Gardens	$4 \cdot 10^{-2}$	$7.6 \cdot 10^{-4}$

An analysis of the results obtained in the present work, as well as of the data reported in the preceding note (1) leads us to the following conclusions:

1. Rubidium occurs in all the plants investigated by us. Its concentration is equal in sea-algae, fresh-water plants and land plants, making up about 10^{-4} per cent, in spite of the fact that the surrounding medium of the plants varies in its composition (according to our earlier data, sea-water contains on the average $2 \cdot 10^{-5}$ per cent Rb; soil, $6 \cdot 10^{-3}$ per cent, and river water about 10^{-7} per cent).

Among dry-land plants there are such as concentrate about 10^{-3} per cent of Rb. The salt-marsh plants belonging to the family *Chenopodiaceae*, *viz. Salsola soda* L., *Salsola Kali* L., *Salicornia herbacea* L., *Suaeda maritima* Dum., stand out for their low concentration of Rb. These plants are rich in Na. The above-listed plants show also an appreciably reduced Rb/K ratio.

In *Salsola Kali* L. it is equal to 0.00018, while for other land plants it averages 0.002.

2. The Rb/K ratio is not the same for sea, fresh-water and dry-land plants. In land plants it is considerably higher than in sea-algae. In the latter the Rb/K ratio shows an average of 0.00037, while in land plants it is 0.002.

A similar relation between the concentrations of rubidium and potassium was also observed in sea-water and soils. The Rb/K ratio in sea-water is equal to 0.0005, in soils it is 0.0028.

This should be interpreted to mean that Rb and K are extracted by plants in about the same ratio in which these elements occur in the surrounding media.

Thanks are due to W. I. Vernadsky, Member of the Academy, and to Prof. A. P. Vinogradov and Prof. S. A. Borovick for the valuable suggestions and help in the course of this work.

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GEOLOGY

ON THE PRESENCE OF TWO COAL-BEARING FORMATIONS IN THE DINANTIAN TIME IN THE URALS

By H. Th. TCHIRKOVA

(Communicated by P. I. Stepanov, Member of the Academy, 10.V.1943)

The phytostratigraphical investigations carried out on the eastern slope of the Urals in the so-called coal-bearing series C_1^h, NW of Egorshino on the Shakish river and in the Podosinino mines, have shown the fossil flora in this series to be contemporaneous with and similar to the one developed in the productive formation of Dombarovka. The following forms have been found here: *Sphenopteridium Keilhaui* Nath., *Lepidophyllum dombarovkense* Tschirk., *Caenodendron uralicum* Zal. At Dombarovka this complex of flora is supplemented by *Lepidodendropsis fusiformis* Tschirk. encountered in large quantities in the Berchogur productive series in the Mugodjars (1). This form is present also in the C_1^h series, on the Kumak river, NW of Dombarovka. An analysis of the flora has shown that *Lepidodendropsis fusiformis* is a form closely approaching *Lepidodendropsis Hirmeni* Lutz. from the Etroeungt beds of Bavaria, where along with the flora a fauna of *Pericyclus* sp. has been also found. The Berchogur series lies in a syncline, directly over the Etroeungt limestones with a fauna of *Productus fallax*, *P. dobroljubovi* Nal., and is conformably overlain by the Karabulak series represented by arenaceous limestones with a fauna of the Upper Tournaisian. On the Kumak river clastic tuffs of basic effusives are interbedded with porphyrites and overlain by coarse-grained sandstones with a flora of *Lepidodendropsis fusiformis* and *Sphenophyllum tenerrimum* Ett. The conglomerates and the sandstones carrying flora are overlain by limestones with a fauna of *Chonetes magna* Rot., *Ch. lebedevi* Rot. and *Ch.* af. *papillionacea* Phill. The fauna is that of the lower portion of the Visean, of the *Seminula* zone. In the Donetz basin to these limestones correspond the $C_1^{\gamma}a$—$C_1^{\gamma}d$ series. Higher up are lying limestones with *Productus elegans* M'Coy. They are followed still higher up by Upper Visean limestones composing the inner portion of the syncline, with a fauna of *Productus* (*Gigantella*) *giganteus* (Sow.), *etc.*

The Dombarovka productive formation is underlain by conglomerates fused with effusives and being in tectonic contact with the productive formation; it is overlain by the over-coal-bearing series with a fauna of *Pericyclus* cf. *rotuliformis* Crik.; still higher up there occur beds of clayey shales with a brachiopod and goniatite fauna (2). In addition to *Lepidodendropsis fusiformis* the productive Dombarovka formation contains large amounts of *Sphenopteridium Keilhaui* Nath. It is a form which has first been described by Nathhorst from the Lower Culm of Spitzbergen. Aside from the two localities named, it has been found by the author in the Podosinino mines in the Middle Urals together with *Caenodendron uralicum* Zal. and *Lepidophyllum dombarovkense* Tschirk. *Caenodendron uralicum* was described by M. D. Zalessky from the Alapaev region and discovered by the author in the Dombarovka productive formation in Kurmansai.

On the Shakish river the productive Podosinino formation rests upon effusives and Upper Devonian limestones and is represented by conglomerates, clayey shales, sandstones and coals. Higher up in the section there occur limestones with *Productus (Gigantella) giganteus* (6). All the four of the sections named contain a contemporaneous and uniform fossil flora subordinate to the Lower Tournaisian. Another complex of fossil flora—a younger one—represented by a large number of genera and species, was encountered by the author in the so-called C_1^h series in the following coal deposits (proceeding from the south): the Baituk river, Bredy, Poltavka, Borodinovka, Boevka, Fadino, Kamensk, Elkino, Cherymshanka and Egorshino. The following forms are present here: *Lepidodendron acuminatum* G., *L. spetsbergense* Nath., *L. glincanum* Eichw., *Lepidostrobus Zalesskyi* Tschirk., *Adiantites bredyana* Tschirk., *A. antiqua* Ett., *A. tenuifolia* G., *Sphenopteridium bifidum* L. et H., *Sphenopteris uralica* Tschirk., *Sph. norosana* Tschirk., *Saropteris rossica* Tschirk., *Rodea Hochstetteri* Stur., *R. patentissima* Ett., *R. gigantea* Stur., *Neuropteris antecedens* Stur., *Archaeopteris Dawsoni* Stur., *A. uralensis* Tschirk., *Sphenophyllum tenerrimum* Ett., *Sph. jegorshinianum* Tschirk. n. sp., *Cardiopteridium parvulum* (Schmalh.), *etc.*

The flora listed above is similar to the one typic of the Morav-Silesia roofing slate and the Ostrau-Waldenburg beds of Silesia. Many of these forms are present in the Moratal beds of Upper Silesia. This complex of flora, rich in ferns and pteridosperms, is by far younger than the Dombarovka one; the latter is entirely absent there.

The coal-bearing formation of the Bredy deposit is represented by quartz and arkose polymikt sandstones, passing into small-pebbly conglomerates, aleurites and coal beds(2); they are overlain by the over-coal-bearing formation with an Upper Tournaisian fauna: *Spirifer attenuiformis*, *Sp.* cf. *grabovi* Rot., *Sp.* af. *tornacensis*(4). The productive Bredy formation at Bredy rests upon different metamorphic sedimentary and effusive-volcanogenic formations of the pre-Cambrian, the lower part of the Ordovician, Silurian, Devonian, and Middle Devonian. The Egorshino coal-bearing formation composed by four areno-argillaceous series 350 m thick (of this C_1^h4 with coals overlain by the non-coal series C_1^h5; after Bai-Balayev synchronous with C_1^2A and corresponding to the limestones of the Middle Visean) carries the same fossil flora as the Bredy productive series.

The same complex predominates in the rest of the coal deposits enumerated. Thus, the C_1^h formation of the eastern slope of the Urals carries at different places a fossil flora of a different kind and different age. In the Berchogur, Dombarovka, Kumak and Podosinino deposits the fossil flora is subordinate to Lower Tournaisian deposits and is separated out by the author in the Dombarovka or western formation; in the Bredy, Poltavka, Borodinovka, Boevka, Kamensk, Fadino, Elkino, Cherymshanka and Egorshino deposits it is subordinate to the Upper Tournaisian deposits or to the Lower Visean. This younger eastern coal-bearing formation is termed by the author the Bredy formation. The two formations correspond to the lower part of the Dinantian stage of the Carboniferous.

The phytostratigraphic investigations made at the western slope of the Urals in the coal-bearing formation of the Kizel main anticline, in the Kospash and Gremyachin synclines, have revealed the scarcity of fossil flora in the coal-bearing formation and its being contemporaneous with the Bredy formation of the eastern slope of the Urals.

In the Bogoroditzky shaft at Kizel basin the following forms have been found: *Sphenophyllum tenerrimum* Ett., *Sphenopteridium bifidum* L. et H., *Stigmaria ficoides* St.; at Gubakha, in the 1st of May shaft, *Adiantites bredyana* Tschirk., *Lepidodendron spetsbergense* N.; the former has been found at the Rudnichnaya shaft, in drill-hole 702 of the western limb of the Gremyachin syncline, and at the Kospash syncline. Elements of the same complex have been met with in the Upper and Lower Gubakha shafts and in the Kizel shafts. In the Lenin and Kalinin shafts *Lepidodendron glincanum* Eichw. and *L. acuminatum* (Goepp.)—common forms of the Bredy formation—have been discovered. In all these shafts the 11 and 13 seams of the Central zone are being worked. At Usva river,

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in the Chkalov shaft, where the second seam of the Varvarinsky zone is worked, fragments of *Adiantites* sp. have been encountered. The coal-bearing formation of the Kizel region rests on Tournaisian limestones with *Productus hyperboreus* Nal. and is overlain by limestones with *P. (Gigantella) giganteus* (Sow.).

At the Chussovaya region the coal-bearing formation rests upon Lower Tournaisian limestones (Kynovian) ([3]). The thickness of the coal-bearing formation of the western slope of the Urals is 250 m, while on the eastern slope it attains 1000 m (Egorshino). The scarcity of the fossil flora in the Kizel coal-be aring formation may be explained by facial conditions. Nearly everywhere, with a few exceptions, the roof of the seams is composed of porous quartz sandstones rich in oxygen, in which the mother substance of the coal has been completely burnt before the formation of coal or impressions of plants; the latter are present in the sandstones only as a bark of *Lepidodendron glincanum* Eichw., *Knorria* sp., *Aspidiaria* sp., or rhizomes and appendices of *Stigmaria ficoides* St. which are present in the bottom of seams in great profusion. Another cause of the absence of flora in the roof of seams is the proximity of the sea, which is evidenced by the mineralized areas of the coal seams at the Kalinin shaft, at Upper Gubakha, at the Lenin shaft, at the No. 5 Rudnichnaya shaft at Kizel. The absence of the Dombarovka coal-bearing formation on the western slope of the Urals is accounted for by the marine conditions which prevailed in the Lower Tournaisian time.

A table for correlating the Lower Carboniferous of the western and eastern slopes of the Urals is adjoined. The left-hand side of the table has been compiled by A. P. Rotai ([7]); the right-hand side part, by the present author (see the inset).

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ZOOLOGY

CONTRIBUTION TO THE BIOLOGY OF FEEDING OF SOME PREDATORY FISHES OF THE BLACK SEA

By A. P. ANDRIASHEV

(Communicated by E. N. Pavlovsky, Member of the Academy, 29.IV.1943)

Our study of the behaviour of fish in search for food was started at the Sevastopol Biological Station of the Academy of Sciences of the USSR in 1939; experiments on blinded fishes embraced the following species: *Scorpaena porcus* L., *Mullus barbatus ponticus* Essip., *Gaidropsarus mediterraneus* (L.), *Gobius melanostomus* Pall., *G. niger* L., *G., cephalarges* Pall., *Uranoscopus scaber* L., *Trachinus draco* L., *Serranus scriba* (L.), *Smaris smaris flexuosa* (Raf.), *Crenilabrus tinca* (L.), *Proterorhinus marmoratus* (Pall.), and some other. The most complete and accomplished evidence has been secured for the first three of the species listed above(8). The present note contains a brief account of experimental and aquarial observations on the feeding biology of some predatory fish species.

Trachinus draco L. Sluggish bottom-dweller of ambushing type. Feeds on small coast fish, and also on shrimps, small crabs (*Portunus, Carcinides, Pachygrapsus*), *Gebia, Idothea, Pagurus. T. draco* lies in wait for its prey being concealed in sand, snatching at it when it approaches quite closely, but also pursuing the prey for some distance. Active during the crepuscular period (A. M. Borissenko). Its main receptor is vision (signal and guidance, controlling rôle but unimportant). Eyes high up, narrow-seated, binocular vision well-developed, especially when looking up and forward. Endures the operation of blinding passably well. Experiments with blinded fishes show that the perception of water vibrations is well developed in them and plays an important rôle in detecting food, especially during twilight (signal, orienting guidance when snatching at the prey). Hofer's reaction (7) positive, but passive; to distant and weak water vibrations the blind *T. draco* responds by lifting its first dorsal fin; to sudden and abrupt vibrations, by an instantaneous and well-aimed throw (up to 30—40 cm; to sudden vibrations close to its head, by snatching. Small fishes put in the aquarium during nearly complete darkness are caught at once. The sense of smell is not developed; nor is the taste reception of the lips. This is made evident by experiments with stained flesh juice: the blind fish gives no response whatever to the juice put in contact with the upper part of its head, nostrils and lips; and it is not until the flesh juice reaches the oral cavity along with the breathing-flow that the fish raises its first dorsal fin. All the species investigated were found to be endowed with taste control of the oral cavity. The lips have a developed sense of touch, but the latter plays no appreciable part in their search for food, like in the rest of representatives of this group of predators(8) which snatch at their prey without any preliminary contact.

Uranoscopus scaber L. Belongs to the same group of predatory bottom-dwellers of ambushing type, though considerably less mobile. Its food consists chiefly

of relatively big bottom fishes* (*Gobiidae*, *Mullus* and others), and to a much lesser extent of crustaceans (shrimps, *Paguridae*). Unlike the ruff, *T. draco* and some others, it is active in its ambushing habit, alluring small fishes by its peculiar «tongue» which is a modified mandibular breathing valve; it is almost completely concealed in the sand which covers its body and flat head save for the mouth slit and small protractil eyes. In wait for its prey *U. scaber* thrusts out its «tongue» through the mouth slit with the reverse respiratory flow, imitating the tuft of gills in *Polychaeta*. It catches the prey at a close distance, scarcely peeping out from under the sand. Its chief receptor is binocular sight which is entirely deprived of any controlling rôle. Is badly affected by the loss of sight and ceases to take food for a long time. We failed to detect any perception of water vibrations in our experimental individuals. Neither olfactory nor external taste organs are developed. As shown by our test with flesh juice, the fringed cutaneous appendages of the lips are not taste-perceptors, their function being solely to screen the oral cavity from the sand sucked in while breathing.

Rhombus maeoticus (Pall.). A sharply pronounced sluggish bottom-dwelling predator of ambushing type (1). The turbot feeds largely on fish; in the region of Sevastopol it is mostly *Odontogadus* (data by K. R. Fortunatova); in the Karkinit bay, *Gobius fluviatilis*; in the Azov Sea, *Engraulis*. Aside from these, the stomach of the turbot is sometimes found to contain other species of fish: *Ophidion*, *Mugil*, *Solea*, *Pleuronectes*, *Smaris*, *Crenilabrus griseus*, *Nerophis*, *etc.*; among crabs it is *Portunus*. The turbot lies in wait for its prey assuming the pattern and structure of the bottom on which it lies; if the school-fish (*Engraulis*) are abundant, the turbot openly and actively pursues them for a short distance in the near-bottom water layer. The chief and decisive receptor in this fish is vision (binocular). The part played by the lateral line system is not clear; some indirect evidence, however, points to the existence of perception of water vibrations. The other receptors seem to take no important part in the search for food.

Zostericola ophiocephalus (Pall.). A predator of ambushing type (3), much more mobile than the three species described above. Owing to the presence of an air-bladder, the specific gravity of these fishes is low (about equal to that of the surrounding water); they freely swim about, leaving the bottom for a long while; they do not lie in wait for passers-by on the very bottom, but hide among *Zostera* and actively hunt for their prey among the algae of the near-bottom water layer. *Z. ophiocephalus* feeds on fish (*Aphya*, *Pomatoschistus*, *Atherina*, *Syngnathidae*) and crustaceans (*Crangon*, *Idothea*, *Spheroma*, *Gammarus* and others), as well as on small molluscs. Its chief receptor is sight (binocular vision poorly developed). They endure blinding fairly well and start feeding a few days after operation, having totally restored their normal reactions. Like in the rest of species of this family, seismosensory perceptions are very strongly developed (alarm and orientating guidance). Hofer's reaction positive, but, contrary to the two other species, it is active (of the type shown by *Gaidropsarus*). *Zostericola* readily finds the source of the stimulus; responds by snapping movements to sudden water vibrations. Smell plays no part in its search for food, but the external taste organs (on lips) are very strongly developed and are likely to be of great import in the active search for food among the thickets of *Zostera*. Being guided by their seismosensory perception and taste reception blind individuals readily discover and find not only active, but also sedentary prey. In this *Zostericola* differ essentially from the typical sluggish predators of the ambushing type (*Scorpaena*, *Trachinus*, *Uranoscopus*, *etc.*).

Serranus scriba (L.). Coast predatory fish of an ambushing habit, actively pursuing the prey from an ambush, occasionally along a considerable distance (1). Being a good swimmer it is still less attached to the bottom than *Zostericola*. Spies for the prey hiding among thickets of algae and in crevices of rocks. Strong and voracious predator, able to swallow up rather large fishes and crustaceans (4). Its chief receptor is the sight, but along with it a considerable rôle belongs

* Up to 88 per cent, according to data by K. R. Fortunatova.

also to the lateral line system. Smell plays no essential part. External taste organs poorly developed. The effect of blinding is of the most painful, disturbing for a long time all the normal functions of the organism. A close analogy to *Serranus scriba* in feeding biology among the fresh-water fishes is offered by the perch, sander and pike (1).

Acipenseridae. Blinding was practised with none of the species; however, observations carried out on the behaviour and feeding of *Huso huso* and *Acipenser güldenstädti* under aquarial conditions are quite convincing. Sight is poorly developed and plays a rather limited rôle, which, like in *Gaidropsarus*, is compensated for by a vigorous development of other receptors. Seismosensorial reception is well developed in all *Acipenseridae*, in *H. huso* in particular. Hofer's reaction positive and active, even in not blinded specimens. Water vibrations are perceived as a signal giving notice of the approach of active prey, and produce a typical hunting reaction. To sudden strong vibrations the hungry *H. huso* responds by a snapping movement. The smell is well developed in all species (signal and guidance), in spite of the absence of tubular nostrils. The nasal capsule is wide open so that a continuous renewal of water at the olfactory rosettes is guaranteed by the onward motion of the fish. The external taste organs are localized chiefly at the barbels placed on the ventral side of the snout, before the mouth, and play an important part in the feeding with poorly mobile benthos, especially in *A. güldenstädti* and *A. stellatus*. When feeding on benthos, the fish dwells near the bottom, so that the dropping barbels almost touch the ground. As soon as the barbels come in contact with an edible object, the fish makes a rapid snapping (sucking-in) movement with its mouth which strongly protracts downward. After being tasted, the food is swallowed, whereas unedible objects caught along with it are partly spat out (pebbles), or swallowed up (sand, mud). The evidence available on the feeding of *Acipenseridae* ([1,5,6]) permits to class the two species investigated among the groups of coast predators which search for their prey near the bottom, being at the same time important benthos consumers. *H. huso* is a typical predator which feeds mainly on fish (*Gobiidae*, *Caspialosa*, *etc.*), and even on natatorial birds and young of seal. *A. güldenstädti* is also mainly piscivorous (*Gobius*, *Benthophilus*, *Clupeonella*), though devoring also crustaceans (*Gammaridae*, *Corophiidae*, *Decapoda*, *Mysidae*) and less frequently, *Polychaeta* and *Mollusca*.

Anguilla anguilla (L.). Our observations on the feeding biology of the eel in salt-water go to confirm the experimental work carried out by Wunder ([7]) in fresh-water aquaria. The sight plays a subordinate rôle in this fish, being compensated for, however, by a strongly developed smell (anterior nostrils tubular, a continuous flow of water through the olfactory capsule is secured by the work of ciliate epithelium), and by a well-developed seismosensorial perception; Hofer's reaction positive, active. The biology of the eel is much similar to that of the group of fish described above.

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PHYSIOLOGY

ON A PROBLEM INVOLVED IN THE THEORY OF BLEEDING

By A. M. DAMIR

(Communicated by A. I. Abrikossov, Member of the Academy, 26.IV.1943)

1. The attitude of the medical world towards one of the oldest methods of applied medicine, the bleeding, was subject to essential variations at different epochs: there were epochs when it was recognized as a panacea, and others again when it was altogether abandoned. At the time being the problem of bleeding is the centre of intense attention. Several aspects of this problem have been thoroughly investigated, as, for example, the physical-chemical alterations in the composition of blood. But many points still remain obscure, and among these belongs in the first line the fundamental problem, *viz.* what is the part of the vascular system which is being evacuated by bleeding. Is the blood removed from different regions of the vascular system or, on the contrary, always from the same part of it? The methods actually available do not enable us to find out whether such a region actually exists (Existenzbeweis). The apparatus we have designed for high-accuracy determinations of the centre of gravity Z of the human body [1] permits to give an unambiguous answer to all those questions.

2. P r o b l e m. Let us consider the circulatory system $\overline{S}$ of the human body and denote by S the total of the blood particles this system contains at a given moment t. It is well-known that to 1 kg body-weight there corresponds, on the average, 83 cm³ of blood. The mass of S measures on the average 5 kg. As the patient under test is supposed to lie immobile on the platform P of our apparatus, the vessels of system $\overline{S}$ are immobile, too, the tonic contractions of the vascular muscles being, of course, neglected. Therefore, although a considerable part (about 3.5 l) of the mass of blood S, being not deposited, is in continuous motion with the time t, S maintains its original shape in the space. This is why S has the shape of the circulatory system $\overline{S}$. Let us denote by σ the gravity centre of the mass S. σ may with sufficient precision be assumed to coincide with the gravity centre of the body, Z, for, according to roentgenographical evidence, the whole vascular system of man reproduces rather accurately the outlines of the human body, the trunks and branches of the vessels spreading throughout it rather uniformly. The systoles of the heart cause in the arterial system waves of pressure and accelerations which run all along the arterial system, resulting in periodical displacements of σ.

Now let us bleed the patient and take from the ulnar vein, say, 400 g of blood. Denote by A the total of blood particles removed from the organism by bleeding, and by B the total of the blood particles that have remained in the body: $S = A + B$. The bleeding will immediately result in a drop of the vein pressure (by some 10—20%) and, after a few minutes, in a drop of the arterial pressure, as well. We have seen σ to coincide with Z (its periodical fluctuations being neglected). Now we have to f i n d o u t t h e c e n t r e o f g r a v i t y β of

the mass B of the blood which has remained in the organism.

Let us assume for simplicity sake that the organism has neither natural reservoirs of deposited blood, nor pathologically stagnant regions. It may easily be seen that under such conditions β will continue to coincide with Z. In order to see this, it is sufficient to follow up the distribution in the organism of the blood A, on the assumption that no bleeding has yet been applied. In this case the blood A, after having passed through the ulnar vein in the form of a continuous, elongated, bent, liquid cylinder, reaches the right heart, where it is mixed with the blood B. This «stirring» makes the mixture of the bloods A and B homogeneous to a degree similar to that of a mixture of alcohol and water. It may be supposed that the process of mixing is attended by vortex phenomena approaching those of a turbulent flow, as a result of which the blood A is homogeneously instilled into the blood B. This also finds confirmation in the well-known fact that every cubic centimeter of blood, whatever its provenance, contains products of the vital activity of any tissue of the organism. And this testifies to the fact that the mixing of the blood makes it homogeneous with respect to any part of the organism.

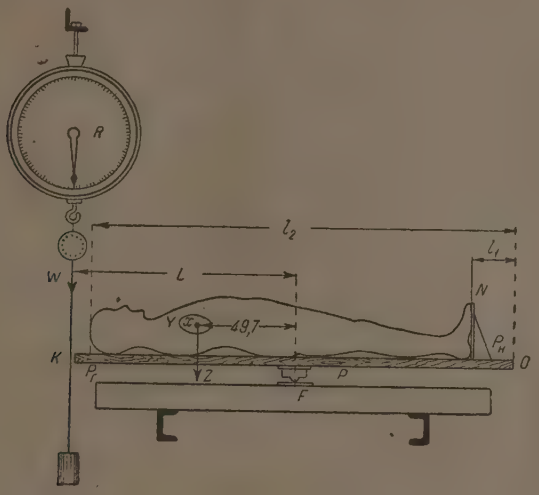
Now, the effect of bleeding consists in eliminating from the organism the blood A. This means that al the particles of the blood A will be eliminated from each mm^3. On the ground of the homogeneity referred to above we assume that the remaining blood B will uniformly fill up all the sections of S and, consequently, β should coincide with σ, *i. e.* ultimately with Z. Thus, on the ground of *a priori* considerations, we arrive at a rigorous proof of the statement: the localization of the gravity centre Z cannot be changed by bleeding, unless there are natural reservoirs of deposited blood or pathological regions of stagnant blood.

The existence of blood-depots and especially of stagnation phenomena make the picture alter materially.

Unfortunately, we possess no clear idea as to the mechanism of the evacuation of reservoirs of a normally deposited blood. We cannot therefore point out what will be the effect of bleeding upon this blood. As to the pathological disturbances of circulation, we have to deal here with the sluggishness of the blood flow or with an irregular distribution, both being mostly due to various heart affections. The latter result in stagnation phenomena which become especially manifest either in the pulmonary round, or in the systemic round, as oedemata of the lungs or of the liver, respectively. In the case of cardiac deficiency, normal reservoirs of deposited blood seem to be evacuated; an increased amount of blood is therefore circulating in $\overline{S}$, owing to which the greatest part of this blood is contained in the distended, swollen veins of the stagnation regions of the organism, overfilling them and travelling through them sluggishly. Nothing except a well-developed mathematical analysis can give us a precise idea of the movement of blood through these regions, and of the way they are affected by bleeding. The applying to this case of differential equations of hydrodynamics is faced here with considerable difficulties, however. In the present case we have to deal with a motion of liquid along such tubes as are not only elastic (in the sense of the theory of elasticity), but fitted moreover with a musculature. The latter continuously imparts them a motion which does by no means depend on the hydrodynamic inert effect of the liquid passing along them. We will therefore content ourselves here with the general remark that the sluggishness of the run of blood through stagnation regions should testify to an elevated pressure in this region. It is therefore natural to expect that the bleeding will evacuate the stagnant region, not because the blood A is removed from it by bleeding, but owing to the adsorbing effect produced at a distance; no single particle of blood may thereby by removed from the stagnation region. The accuracy of this *a priori* conclusion should be checked up experimentally.

3. Experimental. The patient is lying immobile on the platform p

of the apparatus (1) (see figure), until the range of the swings of the needle of the balance R is definitely stabilized; this will mean the setting in of a stationary condition of the blood (*i. e.* of a permanent motion of the one portion of blood, and of a rest of another). Let w be the middle of the arc described by the point of the fluctuating needle. We lift the arresting lever and proceed to the bleeding, taking care that the patient remain immobile. An average amount of about 400 g blood is taken from the ulnar vein. Let w_1 be the new reading of the needle of the balance directly upon bleeding: we now obviously have $w_1 < w$.



Denote by Y a certain imaginary mass within the body of the patient, strictly corresponding by weight to the mass of the blood removed by the bleeding, having the shape of an ellipsoid with the centre at a point x and formally determined by the sole condition that its elimination from the patient's body reduces the original reading of the balance needle w with an accuracy up to w_1.

We have now to find the distance Fx of the centre of the mass Y from the fulcrum F. This distance may be determined in two ways: theoretically, according to the formula $Fx = FK\ (w - w_1)/Y$, where $FK = 104.4$ cm, and experimentally, by displacing the weight Y along the platform P_h and searching for such a point x as the weight Y being located at this point will make us arrive at restoring the equilibrium of the platform P, which has been disturbed by the bleeding. If the apparatus operates without failure, the magnitudes of the two determinations of Fx should coincide. All the 29 patients showed an irreproachable coincidence of the two determinations.

4. Results. We made it our aim experimentally to inquire into the question of evacuation of stagnancy foci by means of bleeding; this is why we had to have recourse to persons affected by diverse diseases. These were classed among three categories, according to the nature of their affections.

The first category comprised nine patients suffering from lesions of the mitral valve, with prevalent stenosis. All of them showed rapidly developing phenomena of stagnancy within the small (pulmonar) round of circulation. X-ray photographs revealed in those patients stagnation phenomena in the hili, and a reduced transparency of the pulmonary fields. The liver was not augmented in volume. According to Lange, they all were at «the first stage of decompensation» of mitral stenosis. A direct testing with the aid of our apparatus showed the centre x of the mass Y to be invariably above the diaphragm and within the

region of the hili. Consequently, the evacuation of the lungs proceeded at the expense of a reduced blood-supply to the right heart.

The second category embraced eight patients suffering also from mitral lesions; in this case the decompensation picture was characterized by a prevalence of stagnation phenomena in the liver and in the veins of the systemic round. All these patients had voluminous stagnant livers. Our apparatus showed the centre x of mass Y to lie below the dome of the diaphragm, accurately corresponding to the liver.

The third category was composed of eleven patients suffering from hypertonia. Being tested at our apparatus, the centre of gravity Z of their bodies was found not to be shifted by the bleeding. This result is in full conformity with the *a priori* statement advanced above. It is a matter for regret that patients affected by cardiac asthma cannot possibly be examined with the aid of our apparatus during their paroxysms. We were able to observe a single case only, where the centre x of the mass Y was found to be located very high, within the upper region of the lungs.

We thus arrive at the following conclusions: bleeding removes the blood from the loci of its pathological accumulation owing to an adsorption effect produced at a distance. If there is no pathological accumulations of blood in the organism, bleeding results in a uniform elimination of blood from the whole vascular system.

It should be pointed out that the relation between bleeding and normally deposited blood stands in need for further investigation.

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HELMINTHOLOGY

AN ANALYSIS OF THE GENERIC COMPONENTS ENTERING INTO THE COMPOSITION OF THREE TREMATODE FAMILIES: *OPISTHORCHIDAE*, *DICROCOELIIDAE* AND *ECHINOSTOMATIDAE*

By K. I. SKRJABIN, Member of the Academy

While studying the phylogenetic correlations between representatives of digenetic trematodes belonging to the families *Opisthorchidae*, *Dicrocoeliidae* and *Echinostomatidae*, I become thoroughly acquainted both with the morphology of the species described and with their distribution among generic components.

The analysis made it evident that while characterizing the species and genera they wish to describe the authors used to base their diagnosis upon most diversified characters, differing as to their taxonomical value.

Owing to this, some of the writers greatly underestimated the generic value of a number of important anatomical elements; as a result, such representatives as ought to be referred to several independent genera, happened to be erroneously referred to a single genus. There are also writers who run to another extreme, raising to the rank of new genera such forms as are species of genera already established.

In the present note I wish to dwell upon a few cases of an incorrect interpretation of the taxonomic signification of certain features of the structure of trematodes, owing to which species which deserved to be referred to new, independent genera have erroneously been included into old genera.

A. Fam. *Opisthorchidae*

1. Tubangui (1928) has described under the name of *Metorchis caintaensis* a trematode which he had found in the liver of *Hypotaenidia philippensis*; the parasite does not belong to the genus *Metorchis*. Unlike the components of the genus *Metorchis*, its sex orifice is shifted towards the level of the pharynx, the ventral sucker is so much displaced anteriorly that its anterior edge almost reaches the posterior edge of the oral sucker. Moreover, the vitalline bodies which begin somewhat behind the intestinal bifurcation, do not only reach the caudal end of the body, but bend on either side anteriorly, forming small medial sections separated by the canal of the excretory system. Because of a vigorous development of the vitalline bodies, the yolk follicles send off on each side of the body two collecting ducts, instead of the single duct characterizing the typical *Metorchis*.

Metorchis caintaensis should be separated as a new genus to which I give the name of *Tubangorchis* nov. gen.

2. Tubangui (1935) described under the name of *Opisthorchis ophidiarum* a trematode from the snake *Lapemis hardwickii* Gray, which does not belong to the genus *Opisthorchis*. Unlike the typical *Opisthorchis*, this trematode has a sharply

pronounced prepharynx which has been described for a single genus of *Opisthorchidae*, the *Phocitrema* Goto et Ozaki, 1930. Besides, the testes of the species described to not lie obliquely with respect to one another, bur along the median line, one behind another, owing to which the excretory canal is not located like in the *Opisthorchis*, but dorsally of the testes, as in the genus *Notaulus* Skrjabin, 1913.

Lastly, the fact of this trematode being parasitic of the biliary ducts of reptiles also distinguishes it from the *Opisthorchis* whose representatives are parasitic of homoiothermal vertebrates only. I thus consider *Opisthorchis ophidiarum* Tubangui, 1935 as being the type of a new genus, to which I give the name of *Evranorchis* nov. gen.

B. Fam. *Dicrocoeliidae*

3. K. I. Skrjabin and B. G. Massino (1925) have described a trematode from the liver of *Muscicapa grisola*, to which they gave the name of *Eurytrema koshewnikowi*. Strom (1940), who entirely reformed the taxonomy of *Dicrocoeliidae*, suggested the idea that this trematode «may be a representative of a separate genus».

At the actual state of our knowledge of the taxonomy of *Dicrocoeliidae* we cannot but agree to Strom's point of view. The situation of the sexual orifice anteriorly of the intestinal bifurcation, as found by Strom, the existence of a manylobate medially situated ovary along with even margined testes, and the powerful development of the uterus whose anterior boundaries pass the level of the pharynx reaching the lateral edges of the oral sucker,—all this makes us isolate the trematode described from the genus *Eurytrema*, and refer it to a new genus. In so far as the analysis of this parasite was made by myself in collaboration with V. G. Evranova, we propose to name this genus in honour of Strom: *Stromitrema* Skrjabin et Evranova, 1944.

4. Braun (1899) described under the name of *Distomum porrectum* a trematode from the liver of a New Guinean bird *Saurophaga saurophaga*, which he transferred in 1902 into the genus *Lyperosomum*. When viewed at the angle of the modern taxonomy of *Dicrocoeliidae*, this species cannot be considered a representative of the genus *Lyperosomum*, as pointed out by Strom in 1940. The extreme length of the body (17 mm) of this trematode against quite a negligible breadth (0.2—0.5 mm), a sharply pronounced shift of the sexual glands towards the equatorial part of the body, a poor development of the vitalline bodies, contrasting with the voluminous uterus, a non-uniform density of the coils of uterus in the anterior part of the body as compared with the posterior part of the parasite's body, made V. G. Evranova separate *Lyperosomum porrectum* (Braun, 1899) as a new genus, to which she gave the name of *Skrjabinosomum* Evranova, 1944.

C. Fam. *Echinostomatidae*

5. Diesing (1850) has described under the name of *Distomum incrassatum* a trematode parasitic of *Lutra solitaria*; it has been studied in detail by Braun (1901), who gave it the name of *Echinostoma incrassatum*.

As a result of the fundamental rearrangement of the taxonomy of the family *Echinostomatidae*, made within the recent years by Skrjabin and Schultz (1938) and Bashkirova (1941), *E. incrassatum* should be separated as an independent genus for which I suggest the name of *Bashkirovitrema n.* g. This genus is distinguished by its very long body (up to 17.5 mm in length), cylindrical in shape, against an insignificant breadth, by an adoral disk with 29 spines forming no dorsal interval, by a vigorous development of the ventral sucker which is strongly shifted towards the anterior end of its body; the bottom of this sucker is implanted deep in the parasite's body, its size being several times that of the oral sucker. The sexual bursa is situated dorsally from the ventral sucker, without passing the level of the latter's posterior edge.

6. Odhner (1902) described the trematode *Stephanoprora ornata* referring to the family *Echinostomatidae*, which he had found in the intestine of *Crocodilus niloticus*. In his work published in 1911 he advanced, however, a different opinion about the characteristic of the genus *Stephanoprora*, believing it to unite characters of the genera *Monilifer* Dietz and *Mesorchis* Dietz. The main diagnostic character of the genus *Stephanoprora*, *viz.* the presence at the cephalic end of the parasite, along with spines of the adoral disk, of a specific armour, was now assigned by Odhner the rank of specific rather than generic distinctions. In her paper of 1941, Bashkirova made mention of this trematode as of a representative of the genus *Mesorchis*. Bashkirova separated the genus *Stephanoprora* into several component genera; the genus *Mesorchis* was given by her an independent position, while *Monilifer* was rightly considered a subspecies of *Echinochasmus*. The trematode *Stephanoprora ornata* was treated in this paper as a representative of the genus *Mesorchis*.

Having analysed the position of *S. ornata* in the system of *Echinostomatidae*, I arrived at the conclusion that this form should be excluded from the genus *Mesorchis* and raised to the rank of an independent genus. In so far as in 1902 this trematode was considered as the typical species of the genus *Stephanoprora* Odhner, 1902, I find it necessary to restore this genus in the sense in which it had been understood by Odhner in 1902, and not in 1911. In other words, this genus should bear the name of *Stephanoprora* Odhner, 1902 nec Odhner, 1911, with a single species, *S. ornata* Odhner 1902, parasitic of the crocodile. The main diagnostic feature of this genus consists in the specific armour of its oral sucker, chitinous spines arranged in a definite order both on the dorsal and on the ventral side of the sucker.

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HELMINTHOLOGY

ON TREMATODES OF THE GENUS *ODHNERIELLA* SKRJABIN, 1915, PARASITIC OF SEA MAMMALS

By K. I. SKRJABIN, Member of the Academy

When navigating in 1912 through the Northern Polar Sea near the Koluchinsky bay, Dr. Starokadomsky happened to dissect a walrus from whose liver he extracted the trematodes which were described by myself in 1915 under the name of *Odhneriella rossica* n. g. n. sp. Although no anterior outgrowths could be revealed in the intestine of this parasite, nevertheless I referred it to the subfamily *Brachycladiinae* Odhner, 1905 (at present *Campulinae* Stunk. et Alv., 1929), which was justified by all the details in the parasite's anatomical structure.

The 60th All-Union helminthological expedition which was working under my guidance at the Far-East Region in 1928 examined by the method of total dissection, after Skrjabin, specimens of *Delphinoptera leucos* whose small intestine was found to contain large trematodes, up to 60 mm in length. Skrjabin and Schulz (1935) investigated those parasites and found them entirely to fit within the diagnosis of the genus *Odhneriella* Skrjabin, 1915. The only difference consisted in that the species found in *Delphinoptera leucos* possessed blind intestine outgrowths which were lacking in *Odhneriella*. One could not help thinking that *Odhneriella rossica* might possibly also have such intestinal outgrowths as escaped observation in 1915 because of the poor preservation of the material. If this supposition be true, the parasite discovered in *Delphinoptera leucos* should undoubtedly be considered the second species of the genus *Odhneriella*.

In 1932 Price published a paper in which he was describing a new representative of the subfamily *Campulinae—Hadwenius seymouri* n. g. n. sp., a long trematode found in the intestine of a *D. leucos*, killed at the American shore of the Pacific. We at once identified this trematode with the form discovered by us in the intestine of the Far-East *D. leucos*, no description of which had yet been published by us by that time.

In order to solve the question whether the discrimination between the genera *Odhneriella* Skrj., 1915 and *Hadwenius* Price, 1932, was based on a safe ground, I undertook a revision of my materials on *Odhneriella rossica*. A thorough investigation of the types showed *Odhneriella rossica* also to possess the blind outgrowths of the intestine, which had been overlooked in 1915.

Thus, the only character by which Price had been prompted to establish his new genus, *Hadwenius*, dropped, with the result that the genus *Hadwenius* Price became synonymous with *Odhneriella* Skrjabin.

Diagnosis of the Genus *Odhneriella* Skrjabin, 1915

Campulinae, with an oblong body whose breadth is about equal at any level. Suckers drawn together; oral sucker larger than the ventral one. Cuticle of anterior body section armed with spines. Intestine supplied with anterior diverti-

cula; no lateral branchings of intestinal trunks. Excretory vesicle long, tubular, stretching up to the level of the posterior margin of the ovary. Sex bursa elongated, considerably exceeding the level of the ventral sucker posteriorly. Cirrus well armed with spines. Testes oval, even margined, arranged one after another in the anterior or posterior third of the body length. Ovary even margined, situated anteriorly of the testes; spermotheca absent. Laurer canal present. Yolk-sacks consist of separate delicate rosettes formed of follicles connected with one another by radially arranged canaliculi. The whole of the body behind the testes is filled up with the yolk-sack rosettes. Anteriorly the yolk-sacks do either not reach the level of the testes, or else reach to the posterior edge of the sex bursa. The uterus lies within the interval between the ovary and the ventral sucker, without passing beyond the edge of the intestinal trunks. Metratherm elongated, unarmed.

The eggs are triangular in the cross-section. The pole opposite to the covercle is thickened. Parasitic of the liver of *Pinnipedia* and of the intestine of the dolphin. Typical species: *Odhneriella rossica* Skrjabin, 1915. Second species: *O. seymouri* (Price, 1932), Skrjabin, 1935.

Table for determining species of the genus *Odhneriella*:

1 (2) Body length 9 mm, from the liver of *Odobaenus rosmarus* . . . *O. rossica* Skrjabin, 1915.

2 (1) Body length up to 60 mm, from the intestine of *Delphinoptera leucos* .... *O. seymouri* (Price, 1932).

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ERRATA

In the article by N. P. Romanov (C. R. Acad. Sci. URSS, XL, No. 7)

	Instead of	Read
page 257, line 9 from top	$= nx - [nx]$	$= nx - [nx] - \frac{1}{2}$
page 258, line 4 »	$\frac{1}{\sqrt{\varphi_{2k}(x)}}$	$\frac{1}{\sqrt{\varphi_{2k}(n)}}$
page 258, line 6 »	$1, \psi_1(x), \psi_2(x), \ldots$	$1, \psi_1(x), \psi_2(x), \ldots, \psi_1^*(x), \psi_2^*(x) \ldots$
page 258, line 3 from bottom	$\sqrt{\varphi_{2n}(x)}$	$\sqrt{\varphi_{2n}(n)}$

Prix $ 0.50